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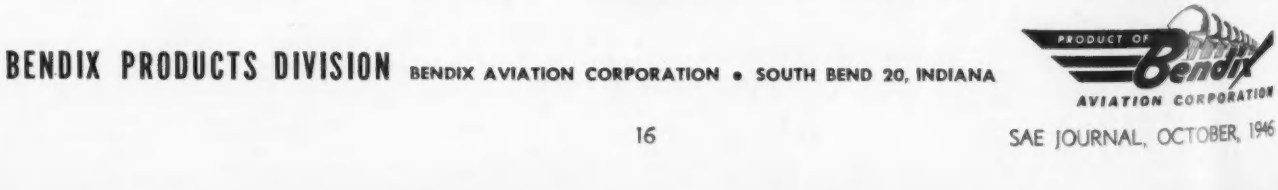

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TURBO-JET to Rule Tomorrow's Skies

BASED ON DISCUSSION BY*

AIR COMMODORE FRANK WHITTLE

AIRCRAFT gas turbines are no longer a laboratory curiosity. So advanced is gas turbine development – particularly the turbo-jet – that it seems reasonably certain that within 10 to 15 years the piston engine will give way to the gas turbine in all aircraft, except possibly the light airplane. In about 5 years, 10% of transport aircraft will be powered with gas turbines and in 10 years a great majority will be.

Right now the industry is deciding whether to wet its feet in the bottomless ocean stretching beyond the horizon or to be content with "the old swimming hole." Shall it be the gas turbine or can we squeeze a few more mph out of the reliable "up-and-down" engine? That is a major question commercial aviation has to answer.

A great deal of thinking and actual investigating has been done. But some of the tentative conclusions reached are not nearly as sound as they appear to be on the surface.

There is a tendency for the industry to shy away from gas turbines, for the present at least, in the air transport field. Reluctance of aircraft manufacturers and airline operators to accept the gas turbine as a superior replacement for the reciprocating engine stems, perhaps, from the comfort of familiarity with the "old" and human conservatism in acceptance of the "new." Gas turbines, especially the turbo-jet,

* Paper entitled "The Early History of the Whittle Jet Propulsion Gas Turbine," by Air Commodore Frank Whittle, Royal Air Force, presented at SAE Metropolitan Section Meeting, July 15, 1946, generated the discussion upon which this article is based. A summary of Commodore Whittle's original paper appeared in SAE Journal, September 1946, p. 26.

offer so many features improving air transportation that they merit a fair comparison with the piston engine.

Typical of the unsound thinking prevalent today is one aircraft manufacturer's analysis of the conventional reciprocating engine versus the turbo-jet. He selected a Pratt & Whitney Wasp Major engine, designed to deliver about 3000 bhp at sea level, supercharged to deliver the same power at 40,000 ft altitude, and the Rolls-Royce Nene, considered to be the most advanced version of the turbo-jet. The Nene is designed to deliver 5000 lb of thrust when standing still, which falls off to some 4000 lb of thrust at a sea level speed of 600 mph.

In design of an air transport powered with a conventional engine, actual range would not be expected to vary with altitude. However, the speed at which that range is obtained would be much greater at high altitudes. Therefore, the manufacturer continues in his comparison, the transport can be supercharged as high as possible so as to increase the speed at which the range is obtained.

Supercharging the 3000 bhp Wasp Major engine at 40,000 ft and assuming a propeller efficiency of 80% at 400 mph, the power available would be 2400 hp. Fuel consumption, he says, is about 0.45 lb per bhp, equivalent to 0.56 lb per hr per thrust hp.

The Nene at 40,000 ft will have a fuel consumption of 1.13 and deliver 1600 thrust hp. The Nene is much lighter, he concedes, and will weigh possibly a third the weight of the Wasp engine as installed in the airplane. But the great difference lies in the fuel consumption which would favor the piston engine.

If the speed is increased to 500 mph, propeller efficiency will start to fall off, although this manufacturer expects efficiencies of 75%. The Nene engine now begins to look a little better as its consumption falls to 0.91 lb per hr per thrust hp compared to a value of 0.60 for the piston engine. Powers available at the 500 mph speed at 40,000 ft are about the same, being 2000 thrust hp for the turbo-jet and 2250 for the Wasp Major. Weight advantage still lies with the Nene.

Jet Superior at 600 mph

At 600 mph, he finally admits, the Nene comes into its own. Assumed propeller efficiency comes down to 70%, conceded to be a bit on the high side. His computations show fuel consumption is now 0.75 for the Nene as against 0.64 for the Wasp. The Nene will now deliver 2400 hp as against only 2100 hp for the Wasp.

Conclusions reached by this manufacturer based on this questionable data are that a jet transport should fly above 500 mph. Since design of airplanes flying at such speeds is difficult at the present stage of the art, he feels that jet transports are still several years away.

This comparison is quite unfair and is typical of thinking in many circles.

It is a comparison of the reciprocating engine of tomorrow with the turbo-jet of today. For example, a fuel consumption of 0.45 lb per bhp in an engine with such high degree of supercharging that its regular altitude is 40,000 ft appears improbable. Claims of 70% propeller efficiencies at 600 mph sound like the propeller business' last plea for survival.

That the Nene is only a third the weight of the hypothetical piston engine is open to debate. The Nene weighs 1600 lb. Is it advanced that the fully installed weight of a piston engine of over 3000 hp on the ground – fully installed with the propeller – is only 4800 lb? Surely the Nene weighs much less than a third the weight of the reciprocating engine.

The fuel consumption issue, too, is in need of some clarification. Much of the weight of a piston engine fighter plane, for example, is directly or indirectly due to the powerplant. A jet powered fighter with an engine one fifth the weight of a conventional engine and 50% greater fuel consumption actually has about the same rate of fuel consumption. It is much lighter and its useful load is 45% compared to the 10% of the conventional engine plane for the same range.

But that is not the whole story for the drag is yet to be taken into account. Design for turbo-jet powerplants allows much more attractive aerodynamic characteristics. The drag of the Meteor Mark IV, shown on p. 17, which holds the world speed record at 606 mph, is 10% below the best piston engine fighters.

But if anyone wants to "crawl" at 400 mph, he very likely will continue to use the propeller – but not in a piston engine. A gas turbine is much better. The gas turbine is very much lighter and its fuel consumption can be made quite comparable with that of the piston engine.

Airline Reluctance Groundless

Airline operators, too, have many fears concerning jet propulsion for commercial transports which should be dispelled. One operator is disturbed by many major problems accompanying high altitude flying required for efficient turbo-jet operation. He feels that pressurization and heating facilities will impose a weight penalty upon the airplane. But cabin pressurization is not a serious problem. It will be a relatively simple undertaking once engineers get to work on its solution.

High speed is another factor bearing heavily upon structural strength. Of some concern to this airline operator is the required ability of the plane to withstand gusts, the force of which increases the faster the airplane flies and the more wing strength required. Not only is the design phase a problem, but from an operating standpoint, how close to the design speed the pilot can operate the airplane is yet unknown.

Turbo-jet proponents discount this consideration as being a limitation. A speed of 500 mph at 40,000 ft corresponds to an indicated air speed of 250 mph at sea level. They endorse the placing of an air high limit on airplanes to avoid going to excessive structure weights. This would impose no hardship on commercial transport operation as the circumstances of operation can be much more readily controlled than in the case of military fighters where the pilot must travel a lot faster than the speed of his pursuer. Moreover, gusts at high altitudes are not severe for at 40,000 ft there is almost a complete absence of gusts of any sort.

Still another disturbing element to the airlines is the question of endurance. Pay load is determined not only on the basis of fuel consumed in flight, but also by the requirement of an adequate fuel reserve in the event that weather conditions or an instrument approach make staying in the air necessary.

This also will be solved shortly. Radar and navigational will overcome weather obstacles so that carrying a dead reserve will be eliminated. One important factor occaing reserve fuel is the stacking of airplanes during landing rations. This and many other phases of airport manageit are in line for sweeping improvements. There isn't ch point in reducing flying time to 500 miles in an hour he passenger is going to spend an hour at each end getting the airport and a good while checking his baggage, then to taxi out before take-off, and finally to fly around for ther half hour to get the "all clear" to land.

That fuel costs become too large a percentage of the total rating costs is another grossly overrated belief still preva-. The figure usually given for fuel costs in air transporta- is about 20%, and that based on the quantity of fuel and the cost of the fuel. But turbo-jet engines use a much er grade fuel than do piston engines and these low grade s are basically cheaper than gasoline.

There is one important factor which should be given conerable weight on this question of fuels; turbo-jet fuels are much safer fuels. They virtually eliminate the danger of g burned alive. They won't go up in flames unless the plane hits so hard that it doesn't matter.

et transports will also satisfy commercial aviation's aim of king air travel available to more people more of the time – pite opinion to the contrary. Operators believe good ser- reliability of the piston engine as demonstrated by the engine failures per hour of operation insures regular ice. They are reluctant to convert to a powerplant with utedly short overhaul periods and less reliability than the procating engine.

Here again experience with turbo-jet operation proves ular opinion in the dark on the true facts of the case. Royal Air Force flight command already recognizes jet ine maintenance and operation as being much more reli- than the piston engine. And new improvements promise idly to widen the gap.

The advantages are heavily in favor of the turbo-jet over "up and down" engine and it is only a matter of time ore piston engine die-hards give up the ghost.

But if the turbo-jet future appears rosy now, it is only ause of the untiring effort of a group of a few men. The tacles to its growth were many; the paths of development lowed often leading to a blank wall. In spite of the finan- difficulties as well as the engineering problems, the turbo- has reached the stage of practical application.

Early Jet History

Looking back at the pioneering effort discloses interesting ts about the engineering trials and tribulations behind jet pulsion. (See digest of Commodore Whittle's paper "Early story of the Whittle Jet Propulsion Gas Turbine," p. 26, *E Journal*, September, 1946.)

First version of the present jet engine appeared in 1930 as tish patent filed by the author, then a Royal Air Force et. In spite of the pessimism then prevalent that low ciencies of turbines and compressors were inevitable, big provements in efficiencies seemed possible.

Few people were convinced of the practicability of jet propulsion for it was not until 1936 that design of the first engine based on the original patent was started. The engine was designed with an optimistic but specific target in mind. It was to propel a clean little airplane weighing about 2000 lb at a speed of 500 mph at an altitude of 70,000 ft, although the initial engine itself was not to be a flying model.

Both a second and a third engine were built before the turbo-jet was considered sufficiently advanced to power a flying airplane. The first flight engine, known as the W1, was installed in an airplane designed by the Gloster Aircraft Co. and flown for the first time on May 14, 1941. The program of flying tests laid down was completed in 14 days without an incident.

The astonishment of those observing the first flight tests was great. One British officer explained to a puzzled bystander who could not comprehend an aircraft sustained in flight without propellers, "That's easy, old man. It just sucks itself along like a Hoover." Another was certain that the airframe concealed a Merlin engine driving a small 4-bladed propeller.

But on that May day in 1941 jet propulsion was truly proven as the powerplant of the future airplane. It was this engine, the W1, that was the forerunner of the many successful turbo-jets built both in this country and abroad. It has ushered in a new era in air transportation which promises to make the world a smaller and very different place to live in.

■

Unusually extensive discussion followed Air Commodore Whittle's Metropolitan Section presentation of his paper, "Early History of the Whittle Jet Propulsion Gas Turbine." The foregoing article summarizes Commodore Whittle's ideas as revealed in his responses to points raised at that session.

Both Commodore Whittle and Messrs. Taylor and Robinson (who wrote "Possibilities of the Turbo-Jet Powerplant" which begins on the next page) predict that turbo-jet engines will soon replace reciprocating engines and dominate the aeronautical field.

All three authors clarify the advantages of jet propulsion and say why they believe its arrival is inevitable. Commodore Whittle gives his answers to many questions currently in the minds of engineers. Mr. Taylor and Mr. Robinson take a look into the future and describe tomorrow's turbo-jet-powered transport.

POWER PLANT for Airlines to b

EXCERPTS FROM PAPER BY **P. B. TAYLOR** AND **S. T. ROBINSON***

ECONOMICS of high utilization of equipment which the use of turbo-jet powerplants makes possible, together with the corollary advantage of reduced fire hazard of non-volatile fuel and the travel comfort arising from the elimination of objectionable noises and vibration are too alluring for airline operators to neglect for long.

It is expected that experimental transport planes will b procured in the immediate future and that the turbo-jet engi will eventually become the most powerful influence in cuttin air transportation costs and making economical flying avai able to the public.

The general term, "Gas Turbine," has been applied to thi new powerplant. It covers a turbo machine wherein energ is added directly to the working fluid, air, by burning of fue in the air mass. The gas turbine must, however, be furthe

* Messrs. Taylor and Robinson, consulting engineers, presented their paper "Possibilities of the Turbo-Jet Power Plant," at the SAE Summer Meeting on June 6, 1946.

"WE are now at the critical point in aircraft development; not because development is blocked, but because so many divergent paths lie before us," Messrs. Taylor and Robinson say in this timely paper from which the accompanying article is excerpted. They continue:

To explore all these paths will require years of effort and large expenditures. To make the wrong choice will seriously retard our development and place us far behind competition. To choose correctly will advance development of aircraft by years with a minimum of expenditure.

Five years ago we accepted the limiting aircraft speeds to 450 mph – limited due to the limits of our knowledge of how to reduce the drag of aircraft and limited by the power which could be made available for flight and use efficiency.

With the advent of the gas turbine, this second limitation was removed. Here was a powerplant of reasonably small dimensions and very low weight, capable of producing power in keeping with current aircraft demands, the efficiency of which increased with increasing flight speed above a practical minimum of 400 mph.

During the years which followed, aircraft were built – some of which made full use of this powerplant – pushing aircraft speeds to the 500 mph mark, but with limited range. Propeller manufacturers, alerted by the potentialities of the turbo-jet, were quick to explore and report on high speed propellers having efficiencies far in excess of those in use.

As a result of the propeller possibilities and the then present compressibility limits, a general conclusion was reached by most observers that turbine propeller powerplants held the key to the future of airplane development and the turbo-jet was neglected.

Recent Trends

In the last two years, however, we have seen the advent of a 100,000 lb commercial aircraft capable of cruising at speeds in the order of 420 mph. We have seen the world speed record for aircraft set at 606 mph with the possibility of its being raised soon to still higher speed.

We hear of guided missiles flying under control at speeds in the order of 2500 mph, and the word "supersonic" has been accepted in the layman's vocabulary.

Thus we find ourselves faced with the decision of whether

b urbo-Jet?

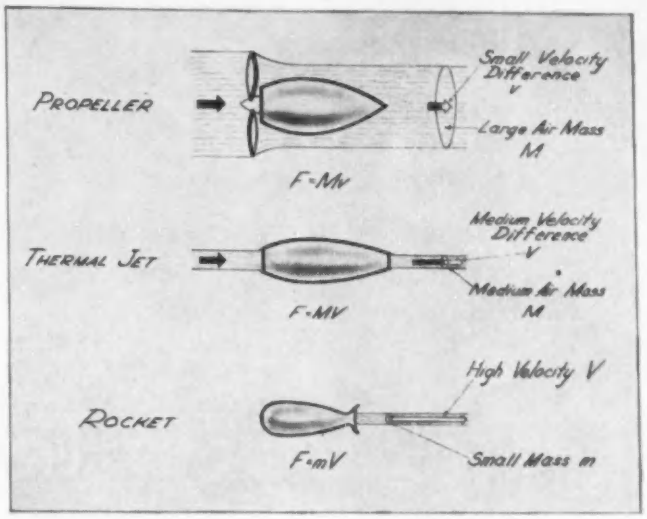


Fig. 1 – Relationship of air mass to velocity in several types of powerplants

fined as an aircraft powerplant according to the method by hich propulsion is accomplished.

In the first case, the major portion of the energy in the orking fluid is extracted in a turbine and the quantity avail- le above that required to drive the compressor is trans- itted through a gear train to a propeller. Such a powerplant designated a turbo-prop engine. Because this simplicity is maintained regardless of size, it offers striking possibilities as a supplement to the reciprocating engine in the horsepower range above the present reciprocating engine level, and as a replacement to present engines, the area of which has not yet been fully determined.

The second case of the gas turbine, the turbo-jet engine, possesses all the revolutionary features of the turbo-prop, to which it adds a new form of propulsion, which, by its basic simplicity, presents possibilities as far reaching to aircraft as the introduction of the screw propeller was to the steamship.

While recognizing the possibilities of the turbo-prop engine in competing with and extending the scope of the reciprocating engine, it is the turbo-jet which completely opens a new area of high speed performance on a basis so compelling that its use can neither be ignored nor postponed. Efficient use of turbo-jet powerplants requires a new integration of powerplant, airplane, flight technique, and ground organization which must be studied in relation to present and future possibilities. At the moment, these possibilities appear so tempting that the industry can be satisfied with nothing less than their full realization.

o build another version of the conventional ircraft but powered with a turbo-prop engine, hich admittedly will greatly enhance its per- ormance, or enter into a new design with all f our latest aerodynamic knowledge and build n aircraft with turbo-jet engines.

The latter step should be taken, even in the ce of current studies that indicated non- xistent engines and propellers could compete ith the turbo-jet engine up to speeds of 600 mph.

Bearing out the authors' contention of turbo- et superiority is their detailed analysis of per- ormance and operation of a hypothetical turbo- et transport they designed. They compare, in he article which follows, a hypothetical turbine- powered plane of their own design with conven- ional airliners, declaring the direct operating ost of the turbo-jet transport to be half that of he DC-3.

Basic Concepts Outlined

The adaption of turbo-jet powerplants to commercial aircraft involves many new problems, an understanding of which frequently goes back to basic concepts – some of which are elementary. To be sure that we start from the same point in our considerations, it is necessary to include a short summary of the basic material which appears in the literature.

All aircraft are propelled by reaction to rearward momentum of a mass of air. This reaction manifests itself in a useful thrust which balances the drag of the aircraft under steady flight conditions. Mathematically, this thrust is equal to the mass flow of air times its change in velocity.

In the case of the propeller powerplant, a large mass of air is moved at a small velocity difference to the aircraft, producing a thrust equal to Mv, as shown in the upper sketch

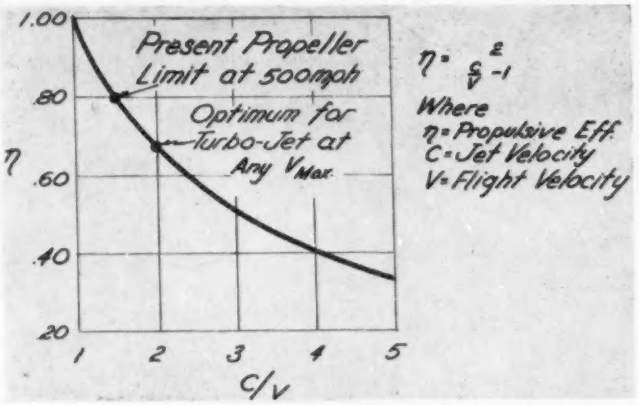


Fig. 2 – Plotting propulsive efficiency versus velocity reveals that a major condition for efficient flight is high aircraft speed

of Fig. 1. The turbo-jet powerplant moves a moderate mass of air at a larger velocity difference to the aircraft, producing a thrust equal to MV, as shown in the center sketch of Fig. 1. Obviously, if the mass of air moved was half of that moved by the propeller, but at twice the velocity difference, the thrust would be the same.

A third form of aircraft powerplant has been included to complete the picture, namely, the rocket. This powerplant is special in that it carries its own oxygen to support combustion, and its thrust is independent of the speed of flight. The rocket moves a small mass of working fluid at a high velocity, producing a thrust equal to mV, as shown in the lower sketch of Fig. 1.

In this case, if the mass of working fluid was 1/10 that of the propeller, but moved at a velocity 10 times that of the velocity difference produced by the propeller, the thrust of the two would be the same. This powerplant, which carries its own oxygen supply, is the only known type which can operate at altitudes above the earth's atmosphere.

Although the conversion of heat energy to thrust in the turbo-jet is direct and does not pass through a turbine wheel, a gear train, and a propeller before setting up the reaction to the rearward momentum of a mass of air, the efficiency of the process depends upon the relative velocity of the jet stream and the airplane, as shown in Fig. 2.

It will be seen from this figure that a major condition for efficient flight with a jet powerplant is high aircraft speed. This requirement is so essential that all the tricks of the trade must be utilized and all engineering compromises biased toward the high speed requirement. This will require the extreme in positive aerodynamic refinement, including thin wings, high wing loading, and efficient flaps.

It will require the elimination of aerodynamic unrefinement by better streamlining, including improvement in windshields, radio masts, landing gear faring, and so forth. And it will also require reduction of drag by operation at high altitude, even for short range flights.

With all of these features and certain others related to the turbo-jet powerplant itself, the boundaries of application between the turbo-jet powerplant and propeller powerplant are at present subject to much controversy, which may be obscuring rather than clarifying the true field of application of each. The winner can be too easily designated by a judicious selection of the basic assumptions used in the comparison.

Another opinion is presented in the form of a generalized curve, purposely neglecting to define a sharp line of demarcation between fields of application. Fig. 3, plotting speed versus range, suggests the broad field of application for each general type of powerplant. In the case of the turbo-jet powerplant, the requirement for high speed flight at altitude is apparent, which fortunately coincides with the principal justification for aircraft as a transport medium.

The turbo-jet does not yet provide a complete answer to all problems, particularly in the range from take-off to flight speed. But the basic mechanical simplicity of the powerplant in all size units, together with the high performance it can develop in an efficient airplane under suitable flight conditions furnishes a compelling incentive to alter conditions so that it can perform to best advantage.

Aircraft Application Requisites

Now let us turn from the brief description of turbo-jet engines to a consideration of their application to aircraft. The special requirements and intimate relation between this type of powerplant and the airplane to which it is fitted immediately set forward certain requirements which must be met.

It is obvious that the basic propulsion efficiency of the jet in relation to airplane velocity dictates high speed as a primary requirement which, fortunately, is in the direction of one of the primary contributions of aircraft. High speed can be obtained most efficiently at altitudes of 35,000 ft and above. Operation at these altitudes becomes a requirement and supposes the use of a pressure cabin to maintain and withstand such pressure.

As the operating range of a jet airplane flying at 35,000 ft is cut more than half at sea level, the cabin pressurizing feature becomes essential to the range and must, therefore, have the same degree of reliability as the other essential elements. We have progressed quite far in this development and scheduled airline operation is now being conducted with aircraft fitted with pressurized cabins.

Acceptable range with a turbo-jet powerplant can be obtained only at high speed or, in other words, in low elapsed time. The crew of this type of plane must, therefore, know where they are going, go there, and land at once.

Alternate landings at other airports are possible in terms of range, but must be accomplished by direct flight to keep elapsed time to a minimum. To operate with safety under

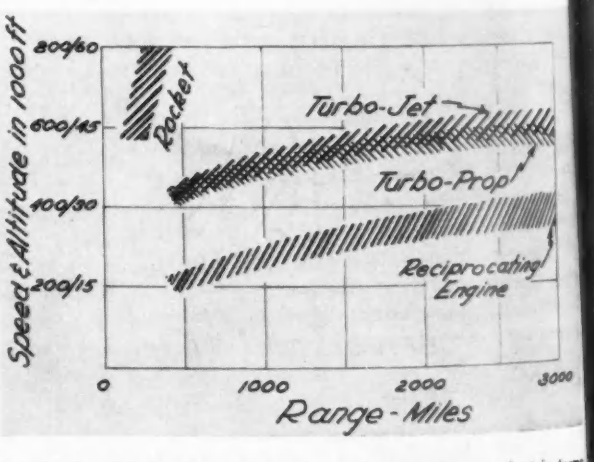


Fig. 3 – Broad field of application for each type of powerplant in terms of speed, altitude, and range

his requirement, blind landing technique and a new traffic ystem which will avoid landing delays are essential in a ighly developed form. Radar and television provide the tools or this accomplishment.

The high speed characteristics of the turbo-jet airplane also bring forward the problem of air bumps with attendant discomfort and possible injury to personnel and passengers. The use of high wing loading is one means of reducing air bump accelerations; but at the new velocities, new operating techniques to minimize this danger will also be required. At high altitudes it is generally agreed, although not entirely proved, that smooth air will be encountered.

The climb to altitude must be accomplished at moderate forward air speed and high angle of attack to eliminate the air bump hazard. In this operation, the turbulent should be entered at moderate velocity and the wing operated at a high angle of attack where it is insensitive – in terms of lift – to small changes in angle of attack. Elimination of serious air bumps can be accomplished for the climb and cruise condition.

Normal descent, on the other hand, occurs at generally increased speed and at a low angle of attack, both of which are unfavorable to avoiding danger from air bump accelerations. For the descent it seems evident that an air brake will be required similar to those used on Navy dive bomber airplanes.

With this equipment, the plane should be operated at cruising altitude until it is within a short distance from its destination, at which time it will descend at a steep angle but at moderate velocity. The reduced velocity would be relied upon to bring the forces of acceleration from turbulent air within safe limits.

Operational Simplicity

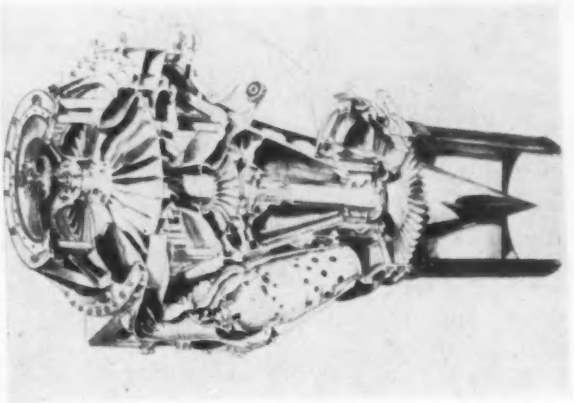
Actual operation of the turbo-jet powerplant is greatly simplified over other types as a single lever maintains complete control of the engine and auxiliaries. The cruising regime is governed to a specific rpm for climb and cruise which can be set by the pilot and will remain substantially constant with altitude change. A decrease in turbine rpm may be required with reduction in gross weight to keep from exceeding airplane limitation.

These, however, are simple adjustments derived from a chart of airplane characteristics. The elimination of mixture strength adjustment, synchronizing adjustment, oil heater, cowl flap, and air heater controls completely eliminates the function of the flight engineer.

Powerplant vibration is virtually eliminated in the turbo-jet engine which is subject only to high frequency vibration arising from the compressor and turbine and the roar of the jet. But since the jet is directional, emerging at a divergent angle from the jet pipe and will be aft of the passenger cabin, objectionable noise from this source should be minimized.

Probably the most troublesome factor from a soundproofing standpoint will be compressor-turbine excitation; although this being of high frequency, will not present a difficult absorption problem. Soundproofing for passenger comfort will require restudy; but the problem is a small fraction of that involved with propeller engines. It is indicated but not yet established

Described in detail by the authors in their original paper was the Rolls-Royce Derwent turbo-jet engine shown. It is a double flow centrifugal compressor type of the basic design originated by Air Commodore Whittle.



This engine derives its thrust solely from reaction to the change in rearward momentum of the working fluid – air. Principal components of the engine are a single stage, double flow centrifugal compressor, 9 straight through combustion chambers, a single stage axial flow turbine, and a jet nozzle.

The Derwent V weighs 1,250 lb, has a diameter of 42.5 in., and an overall length of 83.1 in. less the jet pipe.

Engines of the double flow centrifugal type have a great number of characteristics which recommend them as a powerplant for an initial design of turbo-jet commercial transport. Outstanding in this type of engine is the simplicity and reliability of the compressor system. The broad operating characteristics of the centrifugal compressor lead to ease of matching of the compressor and turbine.

that – for the first time – air travel will afford a degree of comfort approached only by automobile travel on a smooth highway.

Of great importance to any commercial operator is the low maintenance cost of a turbo-jet engine. Actual experience in military service squadrons shows that engine checks can be completed in about 20% of the time required for a conventional engine. A complete engine change can be made in an aircraft not designed for quick interchangeability of powerplants in 12 man-hours, and an engine overhaul can be accomplished in 80 to 100 man-hours.

Responsibility for these surprising statistics lies in the basic simplicity of the powerplant with its small number of moving parts, the fact that the engine is a complete unit requiring little or no supporting components, and absence of accessories such as magnetos, shielded ignition systems, and carburetors. From a mechanical standpoint, there are no pistons, multiplicity of bearing surfaces, valve gear, or propeller maintenance.

The turbo-jet engine, however, is not without difficulties; but they are so limited in number that the total maintenance will always be a small percentage of that of the reciprocating engine. Mechanical components requiring most service are combustion chambers and turbine blades which are subject to high temperature and, in the case of the blades, high stress. As these two items are limiting performance factors, they will always be inclined to be critical.

In the line of accessories, the fuel system with its high operating pressure and plumbing is currently a source of difficulty. Better engineering and the elimination of plumbing by combined units can go far toward improving the performance of this rather involved and complicated unit.

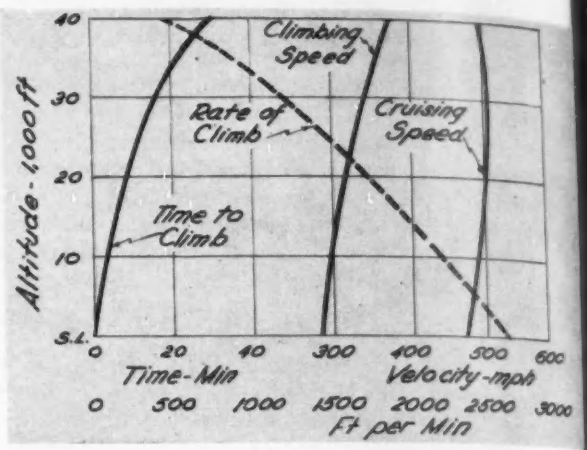


Fig. 4 – Performance characteristics of turbo-jet commercial transport. All performance is presented at normal rated engine speed which represents the maximum power available at take-off

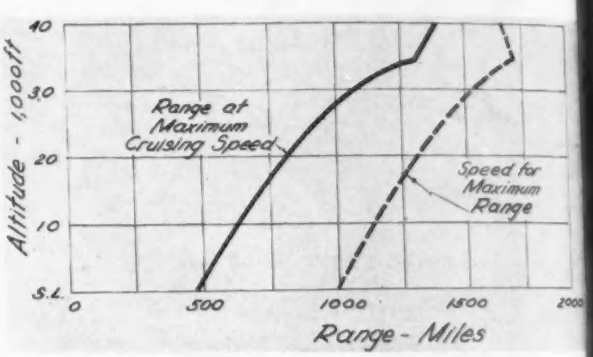


Fig. 5 – Range versus altitude for turbo-jet transport

Fuel Economy Seen

A further point of material saving with turbo-jet engines is the cost of fuel per gallon which, although not possible to determine at present because of unknown factors, will be substantially less than high octane gasoline. The turbo-jet engine requires a free and fast burning fuel which will liberate a maximum amount of heat in a given time without leaving gum, carbon deposits, or excess ash.

Engines have been running on gasoline, kerosene, and fuel oil. The majority of running to date has been on kerosene as this fuel seemed to meet the principal requirements, namely: high heat content per gallon, ability to flow freely at low temperatures, low cost, and a margin of safety from fire as compared to gasoline.

Maximum heat content per unit is extremely desirable to minimize the fuel weight and tankage problem, with emphasis being placed on tankage as the majority of present day aircraft are volume limited. As speeds increase, restricted volume will become even more important.

Pour point is a consideration as the fuel tanks will always be subjected to extremely low temperatures, of the order of —65 F, and auxiliary means of keeping the fuel warm so that it will flow are undesirable. This has been a problem in the use of fuel oil that is difficult to atomize completely at low temperature, particularly at low rates of flow.

It is not possible to make any statements regarding cost until the yearly requirements of fuel, whatever they may be, are known. But it is obvious that the elimination of anti-knock requirements will result in a cheaper fuel than the present high octane gasoline.

Kerosene or some grade of fuel oil will be safer to handle and safer in the event of accident than gasoline. But with kerosene, it will be necessary to purge the fuel tanks with nitrogen or CO_2 as an explosive mixture is formed above the surface of the fuel under certain conditions.

Pertinent characteristics of these three fuels are given in Table 1. Cost has been indicated as a percentage of the cost of gasoline due to the open question regarding this item. These fuels by no means represent the only ones usable, and undoubtedly new possibilities will be developed in which faster burning and higher heat content per gallon and per pound will help to solve the fuel load and tankage problem.

Characteristics of the engine dictate to a great extent basic airplane configuration. The first point to be considered is low installed weight of the complete turbo-jet powerplant, amounting to approximately 0.5 lb per lb thrust. The installed powerplant will represent about 15% of the weight empty of an airplane, in contrast to the usual 30% to 40%. On the other hand, we are faced with a high disposable load in fuel which requires the major fuel tank position to be close to the c.g. of the complete aircraft.

Table 1 – Pertinent Characteristics of Turbo-Jet Fuels

	Gasoline	Kerosene	Fuel Oil
Knock Rating	100/100	None	None
Btu per lb	18,800	18,500	17,600
Btu per gal	112,800	124,800	144,500
Cost in % of gasoline	100	.66	.50
Flash Point in deg F	—40	110	180

This point must be closely watched as speed requirements dictate thin wings which may impose volume requirements on fuel load if all of it is located within the wing.

A combination of several characteristics point to tricycle landing gear arrangement which, coupled with the characteristics of the powerplant, results in an ideal arrangement for this type of aircraft. The tail surfaces must be kept clear of the jet wake in order to preclude the possibility of severe buffeting, not to mention the desirability of keeping the surfaces clear of the high temperature jet.

It is also desirable to have the jet discharge parallel to the ground to prevent the throwing of loose stones and other debris by the high velocity jet. A third point calling for the tricycle gear is the need for take-off in a flying position due to the lack of slipstream over the control surfaces at low speed.

From a utility standpoint, the tricycle gear with a low ground clearance due to absence of propellers, leads to greater convenience in loading and unloading and general ground handling and servicing.

We are of the opinion that, at this early stage in the design of turbo-jet powered aircraft, the engine should be located in the wings. This is because of three factors. First, the importance of keeping inlet duct losses to a minimum; second, the fact that engines are developing so rapidly that a submerged installation usually finds itself with too small inlet ducting shortly after being built, necessitating a redesign of the ducts and associated structure to provide adequate passage area; and third, a wing location of engines will result in greater engine accessibility which is an important factor in operating economy.

Four Engines Sufficient

In considering the number of powerplants to be used in a commercial transport, four appears to be the appropriate number. This is, of course, dictated by the unit size of the engines available in relation to the total power requirements.

More than four engines will lead to undue complications of the engine installation and control problem. Less than four will lead to difficulty in meeting safety requirements for one "engine out" operation, particularly since the turbo-jet engine at present lacks performance at take-off and low flight speeds.

To study the turbo-jet airplane on its own merits, a transport was selected suitable for medium range operation, carrying a maximum payload of 10,000 lb and powered with turbo-jet engines immediately available to commercial operators and at a state of development that would provide satisfactory service.

This airplane has been created without trying to define the physical form other than by the use of characteristics and coefficients slightly better than those existing for the best of present day aircraft. Kept in mind were the rapid advances being made in aeronautics such as improvement in limiting Mach number by the use of swept back wings, the flying wing, boundary layer control, and a host of other aerodynamic improvements. The performance represents what we believe can be obtained in a turbo-jet powered commercial transport at this time. General characteristics of the aircraft are tabulated in Table 2 and a performance summary given in Fig. 4.

Table 2 – General Characteristics of a Turbo-Jet Powered Commercial Transport That Can Be Designed at This Time

Weight empty	27,400
Fuel (2120 gal)	14,350
Crew (3)	750
Payload (40 passengers)	10,000
Useful load	25,100
Gross weight	52,500
Powerplants – 4 Derwent V Engines	14,000 lb thrust
Cruising velocity at 35,000 ft	500 mph
Rate of climb at sea level	2,650 fpm
Time to climb to 35,000 ft	20.4 min
Absolute range at cruising speed at 35,000 ft	1,200 miles
Take-off to clear 50 ft obstacle	3,030 ft

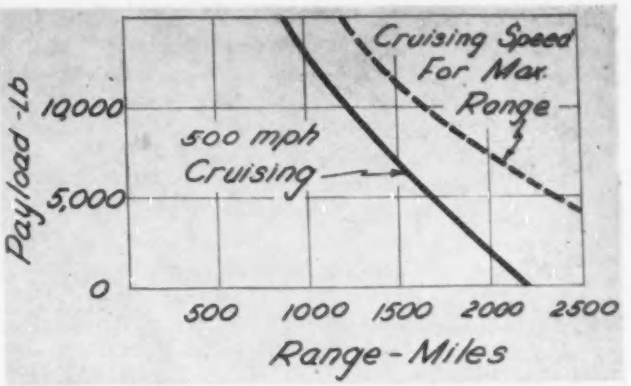


Fig. 6 – Range versus payload performance of the turbo-jet commercial transport for the 35,000 ft altitude condition

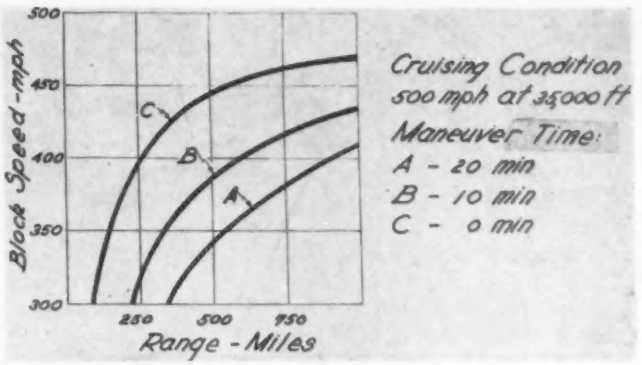


Fig. 7 – Turbo-jet transport block speed plotted against range for 35,000 ft cruising operation into two maneuvering times, 10 and 20 min

All performance presented in Fig. 4 is at normal rated engine speed which represents the maximum power available for cruising. The take-off and subsequent climb is at maximum engine speed corresponding to take-off and emergency power.

Take-off to clear a 50 ft obstacle will limit the use of the aircraft to well established airports. However, this is not the full story as the airplane, being exceptionally clean and lacking propeller drag, will have a long landing run. Unless aerodynamic brakes are installed, this will manifest itself adversely in meeting CAA requirements for complete engine failure on take-off and return to the field.

The rate-of-climb at sea level is quite acceptable, being in excess of that in transport aircraft in use or under construction. It is, however, low, considering the total amount of power available for flight at high speed at altitude.

In Fig. 5, range at cruising speed is plotted against altitude for the speeds given in Fig. 4. The condition of range with one engine out was found quite satisfactory. In fact, to fly for maximum range, it is desirable to do so on two engines at altitudes of 35,000 ft and below. This condition arises because thrust conditions are so low that dividing the requirements among four engines is less desirable than the two-engine condition.

Above 35,000 ft, four engines must be used as two will not

produce sufficient thrust to maintain flight. It will be noted that maximum range falls under this condition.

The 35,000 ft altitude condition, which has been selected for subsequent discussion of the performance of the airplane, has been replotted in Fig. 6 in terms of range versus payload. This is a straight conversion of payload into fuel, assuming that fuel is not volume limited. In Fig. 7, block speed has been plotted against range for 35,000 ft cruising operation into two maneuvering times, 20 and 10 min at both ends of the run. Zero maneuvering time has been indicated as a reference.

This figure emphasizes the necessity of reducing maneuvering time to the minimum possible for short range operation. With present maneuvering times, the economics of high speed operation cannot be utilized in full, especially at ranges less than 750 miles. No more striking example of the necessity for reduction of airport time can be made than this analysis of high speed operation over short ranges.

Turbo-Jet Limitations

Several deficiencies of the turbo-jet powerplant also stand out, namely: its poor climb characteristics which lead to a reduction in block speed as the aircraft must get to 35,000 ft to operate efficiently, and its high fuel consumption leads to difficulty in building sufficient tankage for long range operation in revenue-producing aircraft.

It is again stressed that these figures show absolute range, included distance traveled in reaching altitude and without any reserve. In transposing these absolute ranges into practical range, cognizance must be taken of current CAA requirements for range and reserve fuel. These requirements, as developed for present aircraft and navigational aids, call for landing at an alternate airport in event the scheduled destination is unavailable, plus 2 hr reserve fuel for transoceanic flights and 45 min for domestic flights.

This, of course, calls for a flight plan to be prepared immediately prior to departure and generally additional range equal to 10% of the alternate destination is included to cover wind forecast and possible error in navigation. This additional range will not impose any particular hardship on a turbo-jet transport as it represents but a few additional minutes of flight, nor would 45 min additional endurance.

Two hours of endurance, however, could on a short over-water hop, almost double the fuel load. The requirement for this additional range and endurance arises from one thing – the vagrancy of weather – which can change due to the long exposure to which present aircraft are subjected. Another contributing factor is the necessity of having to wait your turn in a stacking procedure before landing in case the airport at destination does close over. Since the exposure time of a turbo-jet transport will be drastically cut, the time in which weather at the destination can change will be reduced.

Considering both of these conditions, a series of practical ranges has been calculated for the hypothetical transport on the basis of 10% additional range, as now generally used to cover errors in navigation and prediction of winds. Also assumed were 45 min endurance cruising at 500 mph at 35,000 ft. This range, directly applicable for domestic runs without making a concession to the turbo-jet transport, is listed in Table 3 with corresponding payloads.

Table 3 – Range and Payload of Turbo-Jet Transport with 10% Reserve plus 45 min Endurance

Payload	Range Miles
10,000 lb	840
7,500 lb	1,125
5,000 lb	1,345

Table 4 – Flying Time of Turbo-Jet Transport Between Principal American Cities in Block to Block Speeds

New York to Chicago (non-stop)	1 hr 45 min
New York to Miami (one stop)	3 hr 20 min
New York to St. Louis (non-stop)	2 hr
New York to Los Angeles (two stops)	5 hr 55 min
Chicago to New Orleans (non-stop)	1 hr 55 min
Seattle to Los Angeles (one stop)	2 hr 40 min

In block to block speeds, between a few principal cities in the United States, operation of such an aircraft would result in the flying time given in Table 4. Thus we find in such an aircraft a means of shrinking travel time to one-half or less of present values with tremendous implications to our national and international economy.

Operating Cost Computed

Without going through the full list of operating accounts, but depreciating the aircraft, engines, and radio, considering crew pay, fuel cost, maintenance, and insurance, an annual operating cost was established for the hypothetical jet airplane. Assuming a utilization of 8 hr a day on an average 750-mile run, a cost per mile was established. On the basis of capacity operation, the direct operating cost per seat-mile is but slightly over one cent.

As compared with a DC-3, which has become the standard in air transportation, this aircraft can be operated for approximately one-half as much. Thus the high speed airplane not only advances our transportation objectives but, because of high utilization, makes possible a new economy in air transportation not equalled by present types.

With the airplane outlined, it would be possible to cross the continent in 6 hr in quiet comfort, with conversation or study during the trip easily possible. Mail could be delivered to any point in the United States within 12 hr, an objective of great value to business and personal relationships. Vacation travel need not be limited to short range by time, or to a considerable degree by money, which will greatly expand the usable facilities.

Can Be Had Now

The airplane proposed is selected as being readily available within present knowledge and immediately useful for domestic operation. Other equally attractive turbo-jet powered aircraft are possible, including the recently announced British 85,000 lb flying wing which is designed to cross the Atlantic from New York to London in 6 hr. However, the surface of the potential development of these engines has just been scratched. In the next few years we will see improvements in performance and economy which will manifest themselves in still greater utilization and lower operating cost.

Procurement of an aircraft of the type proposed should be initiated at once. This would permit working out of the operating problems attendant with any such piece of new and radical equipment. Such a move is good insurance; when the next equipment procurement cycle comes around, our airlines will not find themselves lacking in the technique necessary for full utilization of our latest advances in the science of air travel.

Biggest SAE TRACTOR Meeting Probes Future In Vigorous Discussions at Milwaukee

CLIMAXING the largest and what SAE members almost without exception called the best planned and most instructive of the 11 SAE National Annual Tractor Meetings, Fowler McCormick, chairman of the International Harvester Co., declared to 550 members and their guests who attended the dinner at Hotel Schroeder, Milwaukee, Sept. 12, that America's economic health depends upon the extent to which the farmer remains healthy.

The slim, youngish looking Harvester Board Chairman, grandson of the company's founder, praised the automotive engineer for having brought precision techniques, better and smaller powerplants, stronger, better and lighter steels, anti-friction bearings, rubber tires and modern service instead of the blacksmith shop to the agricultural industry. A. T. Colwell, Thompson Products vice-president, was toastmaster.

(Left to right) Fowler McCormick, chairman of the board of International Harvester Co., the SAE National Tractor Meeting dinner speaker, with Toastmaster A. T. Colwell and SAE President L. Ray Buckendale at the speakers' table

By way of introduction to his topic, "Present Horizons in Agriculture," Mr. McCormick remarked that 40 or 50 years ago "a group like this would have been breeders and livestock men."

Eighteen years ago he told a meeting in Chicago that it was time that the industry stopped considering itself as an implement industry; that it must begin to think of itself as an automotive industry, because only then the industry could think in more precise terms and use more precise techniques.

The horizon in agriculture can be divided into sectors, the speaker told his audience. Three are pretty heavily clouded, while the other seven look optimistic.

The three dark sectors which the farmer has to face are a decline in prices, affected by our national economy and partially predictable; an increase in the price of goods and services purchased by the farmer, and scarce and high priced labor due to a continuation of the movement of labor to the cities.

The seven optimistic sectors are well organized cooperatives which have secured better prices; good government representation for the farmer; the great promise of chemurgy; better soil, crop and livestock practices now at the disposal of farmers through Government agencies, colleges and the work of the 4-H clubs; better homes, buildings and equipment; better tractors and farm implements.

Mr. McCormick urged tractor engineers to study the farmers' needs and to work for lower first cost of tractors; lower service and maintenance costs; better performance of tractors; greater ease of operation; more comfort for the operator; greater ease in the attachment of tools; better appearance, and a saving in man power.

Tractor engineers should do these things not only because it is their livelihood, but because there is no group of citizens in the country more worth doing for than the farmer.

"The farmer," he concluded, "remains the greatest individual capitalist in the country, and if we can maintain him in this position we will be doing something very worthwhile for our country."

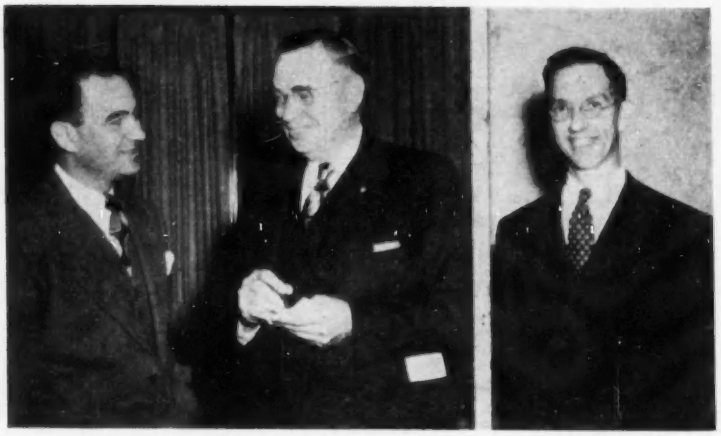
Honors 30 Year Tractor Activity

SAE President, L. Ray Buckendale took advantage of the occasion to celebrate the 30th anniversary of tractor activity in the SAE in his dinner talk, and to introduce to the SAE members present the 1947 presidential nominee, C. E. Frudden, consulting engineer, Allis-Chalmers Mfg. Co.

In 1916, he pointed out, the Society of Tractor Engineers merged their interests with those of the Society of Automobile Engineers, and the name SAE was changed to the Society of Automotive Engineers to encompass its broader interests.

Mr. Buckendale cited the benefits derived by the Society's 14,000 members from the constructive achievement of the technical and administrative work that has gone forward under the guidance of the Tractor & Farm Machinery Activity since its inception in 1935, lauding leaders of this group.

He praised the striking record of the SAE Tractor War



G. W. Curtis, general chairman of the meeting (center) chats with C. T. O'Harrow, SAE Milwaukee Section Chairman (left). At the right is SAE Tractor Vice-President E. A. Petersen

Emergency Committee during the recent war and the continued progress of its postwar successor, the SAE Tractor Technical Committee.

In calling upon Mr. Frudden, President Buckendale paid tribute to the tractor industry for the honor of having the 1947 presidential nominee selected from among its leading members.

Mr. Frudden called this recognition an invitation to join more thoroughly in the activities of the Society.

Top Ranking Industrialists Attend

At the speakers table was the largest group of tractor industry top executives ever to attend an SAE tractor meeting, a fact that was noted by Toastmaster Colwell when he praised SAE Vice-President Petersen and General Chairman George W. Curtis, before the table introductions were made.

Sessions, Meetings, Committees

Total registrations for the two-day tractor meeting passed the 700 mark for the first time in the 11-year history of the event. Morning and afternoon sessions were attended by from 400 to 550 members and visitors.

A well accepted innovation introduced by General Chairman Curtis was the breakfast meetings on Wednesday and Thursday, attended by the session chairmen, readers of papers and discussers for the day. Thus, all last-minute details were consolidated and proper timing of programs was effected.

Other important group and committee meetings held during the meeting included the SAE Council; the Tractor and Farm Machinery Activity Meetings Committee, which laid plans for tractor participation in the SAE Annual Meeting in Detroit next January; the regular Tractor Technical Committee breakfast; the Diesel Engine Fuels Committee luncheon, and the Controlled Soil Testing Committee dinner.

On Friday, following two days of sessions and tractor business meetings, the annual golf tournament sponsored by the SAE Milwaukee Section, was held at Ozaukee Country Club. The golf dinner and awarding of prizes took place Friday evening.

Working with Tractor Vice-President Petersen was the general committee, headed by Mr. Curtis, manager, Milwaukee Div., Timken Roller Bearing Co., and his committee members, C. E. Frudden, C. T. O'Harrow, and R. A. Johnson, all of Allis-Chalmers Mfg. Co.; R. K. McConkey, Timken Roller Bearing Co., F. C. Schulze, Waukesha Motor Co., and T. L. Swansen, Bostrom Mfg. Co.

Active in handling many detail arrangements under the direction of Milwaukee Section Chairman C. T. O'Harrow, was the Reception Committee, headed by C. L. Spexarth, Harley-Davidson Motor Co., and including L. L. Bower, E. E. Bryant, C. H. Duquemin, G. J. Haislmaier, E. H. Lichtenberg, R. K. McConkey, H. M. Schudt, G .D. Sickert, R. L. Switzer, H. M. Wiles and L. A. Wilson.

1947 SAE Nominees

Nineteen forty - seven SAE Presidential Nominee C. E. Frudden (right) and Ben G. Van Zee, 1947 nominee for SAE vice-president representing Tractor and Farm Machinery Activity. Mr. Frudden is consulting engineer of Allis-Chalmers Mfg. Co. and Mr. Van Zee chief engineer of Minneapolis-Moline Power Implement Co.

Interest Packed Sessions

Morning and afternoon technical sessions on September 11 and 12 were packed with papers and discussions on a variety of subjects which ran the gamut of self-propelled implements, novel dynamometer methods of measuring power used for threshing and propelling, integral and mounted equipment, two-way tractors, tractor efficiency, soil dynamics, diesel engine requirements, diesel power economics, air-cooled diesel engines, and discussion relating to all subjects. More than 40 people actively participated in these sessions.

Novel Dynamometer Explained

Development of a novel dynamometer for separately measuring the power for threshing and propelling power-take-off driven combines, was reported by Prof. G. W. McCuen, who reported on work done at Ohio State University. His studies covered the power required to thresh different kinds of grain and show which are the toughest, which require the most power, which show the greatest grain loss and which can be worked the most efficiently.

These studies, something which the average tractor engineer would not undertake, have developed the

Industry's Top Executives Attend 1946 SAE National Tractor Meeting

1. Walter Geist, president of Allis-Chalmers Mfg. Co., photographed just before the dinner. 2. A. W. Phelps, president of Oliver Corp., with the company's chief engineer, L. A. Gilmer, right. 3. W. K. Hyslop, president of Massey-Harris Co. 4. L. R. Clausen, president of J. I. Case Co., left with W. C. McFarlane, president and general manager of Minneapolis-Moline Power Implement Co. 5. J. L. McCaffrey, president of International Harvester Co., left, and the company's vice-president in charge of engineering and patents, Albert W. Scarratt

means of obtaining the lowest losses per acre for various grains and for various sizes of equipment.

Professor McCuen built the first portable belt-driven dynamometer for grain thresher tests in 1922 at the Department of Agricultural Engineering. A testing technique was developed and equipment built which made it possible to control the many variables inherent in this kind of work. Feeding rate is controlled by a bundle meter. A straw and chaff divider was built to determine cylinder, rack and shoe efficiency accurately, from these three sources of thresher or combine harvester power losses.

History of testing and studying of combines almost paralleled thresher test work. The thing most needed to replace the electric belt dynamometer was a power-take-off dynamometer, sturdy enough to take the punishment of field work and reasonably accurate. This power-take-off dyna mometer was fully realized in 1941. In the harvest season of 1942 a series of tests was made on combine harvesters, and on corn pickers in 1943.

W. H. Worthington, John Deere Tractor Co., thought it a sad commentary on the stationary thresher industry that 80 years had passed before power requirements of the individual functional components were measured – and then by the facilities of a state university.

The results of grain losses over the racks, as reported by Prof. McCuen, evidences lack of scientific procedure in equipment development. Losses of separation at the "gate" adjacent to the cylinder may properly be included with straw rack losses. Each square foot of separation is far more effec-

turn to p. 108

INTERCITY DESIGN of

BASED ON A PAPER BY **T. L. JAMES***

INTER-CITY motor coach operators need vehicles which will run two million miles, will not cost more than $20,000, and will not weigh more than 19,000 lb. The vehicles would have considerably more power than those offered today, would be equipped with better torque converters, embody improved air conditioning, have two-way radio, and increased passenger comfort.

Essential to long distance bus operation is more engine output for both gasoline and diesel powerplants. The company's General Motors 707 and 671 diesel, the ACF 180 and Hall-Scott 190 range from 165 to 220 hp – depending upon injectors, compression ratios, and sizes of sleeves. Although these engines are, in the main, satisfactory, buses cannot maintain their position in traffic. Automobiles are forced to pass them on a hill. Motorists resent this slowup in traffic, and in heavy traffic feel that buses are a hazard on the highways.

Although we are not sure as to how much more power is needed, an increase of 50% in horsepower output, but with no increase in overall weight, would be desirable.

Because engines are generally underpowered for the task imposed upon them, they are forced to run long periods at maximum rpm. Therefore engine life is relatively short.

The Twin Coach Co. is developing a bus with two 180 hp powerplants. At a lower rpm these engines develop 150 hp and with both engines, or a power output of 300 hp, a speed of 60 mph appears attainable with the engines operating at about 65% capacity. It is not my feeling that any bus should be operated at a speed in excess of 60 mph over present highways.

Being able to develop ample power at these lower engine speeds of 2000 to 2100 rpm, instead of top speed above 2600 rpm, will mean a much longer engine life.

For several years our company has had in operation more than 50 General Motors diesel buses. These 671 diesels have, in the main, been satisfactory, but they do not have sufficient power for our operation.

We believe that many dollars can be saved with buses powered by two engines instead of one in respect to road failures. The average cost to our company per road failure in 1945 was $115.45, but in some of the territory through which we operate road failures cost as much as $400. Distances are large and it is sometimes necessary to travel far to relieve a failure. It is 750 miles between Salt Lake City and Los Angeles, and between Salt Lake City and San Francisco.

If a failure occurs midway between these points the cost of returning the bus can be very high, and more than 70% of all road failures on our system in 1945 were attributable to items in the powerplant, clutch, or transmission. The engine is our number one problem, and I am sure all the engine manufacturers are conscious of these deficiencies in so far as our type of bus operation is concerned.

Torque converters, either semi- or full-automatic power transmission types, are our number two requirement. Fluid drive and other types of torque converters have been successful on automobiles. We believe that it will soon be possible to develop such devices for heavy-duty equipment. Perhaps the third point in order of importance is that we need 37 good seats in inter-city buses.

We have 35-ft buses, two feet longer than a previous model. But we gave the passengers the extra space instead of installing four more seats. We have a minimum seat space of 38 in., with one or two with 40 in.

Two-way radio has an important place in inter-city bus operation. Considerable work is being done in this field in Chicago. Mobile radio equipment has been installed in 100 buses in the Chicago area by seven companies. About ¼¢ per bus mile is now being spent for communication, and it has been indicated that a system-wide radio setup for all bus lines could be established and operated at a cost not to exceed this.

Airconditioning equipment will continue to advance. De-

(Turn to page 33)

* "Bus Design from the Operator's Viewpoint – Inter-City Service," by T. L. James, Burlington Transportation Co., was presented at SAE Summer Meeting, June 4, 1946.

Urban and Inter-Urban

Authors of these two SAE 1946 Summer Meeting papers, presented here in condensed form, agreed upon these requirements for the motor coach of the future:

- **More engine hp to meet traffic pace**
- **Improved transmissions, preferably automatic types**
- **More adequate heating and ventilation of buses, including a source of heat supplemental to the**

CITY SERVICE of BUSES

BASED ON A PAPER BY **A. F. McDOUGALD***

DESPITE the many engineering improvements in the design and construction of city motor coaches, bus line operators hope bus and equipment manufacturers will continue their efforts in view of the mounting labor and maintenance costs which face the bus lines from coast to coast.

Objectives agreed upon by many of the urban bus operating engineers are offered, but it must be borne in mind that this is not an attempt to set specifications for a standard vehicle. Such specifications would curtail improvement. However, in the interest of safety, ease of operation, and simplification, uniformity of design of many items of equipment would be helpful.

The "dream" bus of the future will be developed eventually, but in the meantime improvements based upon these suggestions will permit the operating industry to better merchandise its commodity, and will allow more people to be moved with fewer vehicles.

As a general performance requirement, urban motor coaches should be able to accelerate rapidly, climb grades, decelerate, and be generally maneuverable so the driver can hold his place in traffic and maintain fast schedules.

Passenger safety, comfort, and convenience are prime objectives. This implies smoothness and quietness of operation. Temperature, humidity, freedom from drafts, adequate lights, comfortable seats, pleasing interiors, convenient and safe entrance and exit doors and steps, facility of movement through the coach, means for rapid fare collection, and visibility through windows for both seated passengers and standees are general requirements.

From the standpoint of the urban motor coach operator, the design, construction, and material of the bus and its components should be such that:

- Reasonable operating life – without excessive maintenance – may be obtained;
- Accessibility of components, provisions for unit replacement, and standardization of parts should be achieved to a far greater degree than at present;
- Dependable operation, with a minimum of road failures, may be expected.

Accomplishment of these objectives will reduce costs of operation and maintenance of the vehicle.

In view of increasing manufacturing costs, three chassis sizes for urban coaches are recommended:

- Small: seating from 20 to 29 passengers;
- Medium: from 30 to 36, and
- Large: over 40 passengers.

State and local regulations hold width down to 96 in., although a number of agencies are seeking to have this increased to 102 in. The average allowable length is 35 ft.

Floor heights should be held to 32 in.

Step dimensions should be standardized. The lower step should not be higher than 15 in., and tread depths and riser heights should be of uniform dimensions. Doors should have a minimum clear opening of 30 in.

The outside body corner turning radius should not exceed 40 ft, and front and rear overhang should not be excessive in order to eliminate a traffic hazard.

Considerable importance is attached to front end design by urban coach operators, because of its effect on safety, efficiency, and public good will. Much can be done to increase comfort of the driver by improving visibility, relieving his fatigue, and improving his reflex action.

Passenger movement during boarding, alighting, and fare collection and transfer transactions should be kept in mind. Proper route and destination signs, and general smart appearance of the motor coach help build good will.

To attain these objectives, certain standardization is essential in front end design. The driver's horizontal arc of clear vision should be 180 deg, and he should be able to see the street within a reasonably close distance while in his normal seated position. Overhead traffic signals should be easy to see, and he should not be crowded by passengers.

* "Bus Design from the Operator's Viewpoint – City Service," by A. F. McDougald, Capital Transit Co., was presented at SAE Summer Meeting, June 4, 1946.

perators Agree:

engine cooling system

- **Better styling of the vehicle – to increase its appeal to the traveling public**
- **Overall width of 102 in. of larger sized vehicles, and 96 in. for smaller buses**
- **Accessory units more conveniently located – to speed up maintenance, especially in view of higher labor costs**

CITY SERVICE

(cont. from p. 31)

Heating and ventilating is one of the most serious problems faced by transit management today. Recently a transit executive said: "Our patrons can't understand why they have to endure overheated, poorly ventilated buses, even to the extent of perspiration-soaked clothing on a cold winter's day, in a world which takes pressurized airplane cabins, radar, and blind flying as a matter of course."

Motor coach heating and ventilating systems should provide a positive pressure within the vehicle at all times while the bus is in service. Fully automatic in operation, the system should hold to a plus or minus of 2½ F of the specific mean temperature. Its capacity should be sufficient to provide 20 cu ft of outside air per minute per seated passenger, and a temperature differential of 60 F at zero ambient. Air cooling systems should maintain a 15 F differential at 100 F ambient temperature.

What the City Service Coach Operator Wants

An engine with ample power to provide quick acceleration and grade climbing

Automatic transmissions which will permit drivers to hold their place in traffic, and to speed up schedules

Minimum center-to-center spacing of transverse seats 28½ in.

Three chassis sizes, two widths of 96 and 102 in., and lengths up to 35 ft

Improved comfort for the driver, including proper ventilation and lighting

Interior decoration considered in terms of public appeal

Adoption of new developments in materials for strengthening and improving the looks of side sheets of buses

Easing of the driver's physical job by improving steering mechanisms

Air compressor drives designed so that the compressor operates only when compression is necessary

Higher voltage electrical systems – increased capacity, efficiency, and reliability of starting motors

Application of unit replacement system to all equipment on the vehicle

A parts standardization program by coach builders and accessory manufacturers to increase interchangeability and reduce operation costs

Removal of the mystery from crankcase ventilation, and provision of adequate ventilation and more oil sump capacity

Heating and ventilating – improvement

Although it is expected that engine heat will continue to be used, some type of supplementary heating will probably be required. Present equipment poses a considerable maintenance problem with the large number of heater and hose connections.

Lighting should produce an illumination level of 15-ft candles over the entire normal reading area at each seat, and this should be maintained throughout the life of the bus. This calls for further development of incandescent equipment, and probably for fluorescent lighting, providing the same batteries and generators can be used.

Most operating companies feel that seat spacing should be identical with window spacing, and that minimum center of seat spacing should be 28½ in. for transverse seats. Material, trip, and construction should be such as to reduce maintenance to a minimum.

Partly in the interest of temperature control and also to subdue noises, adequate insulation of the coach body is important. All metal roof material is generally preferred. Considerably more development is needed to improve floor covering material.

More attention should be given by coach and accessory manufacturers to interior decoration to produce a more favorable passenger reaction.

A major maintenance problem is keeping the side sheets of the bus in good condition. Color matching for touching up is time consuming. The operators hope that new developments in apply metals and plastic material will solve some of these body maintenance difficulties.

Powerplants are not adequate for urban bus operation. The majority of operating companies suggest these improvements:

Blocks should not distort excessively. This would permit use of precision bearings without line boring.

Long life removable sleeves are needed.

Pistons should have better temperature characteristics to avoid excessive head, ring, and skirt temperatures.

Piston rings should be improved to prevent excessive oil consumption, plugging of oil passages, and to control blowby.

Bearings need improved life, better locking arrangement, ease of setting and replacement.

Valves and valve mechanism need improvement, as do crankshafts.

Cooling systems tend to leak too freely, and otherwise lose coolant. The systems should have provision for quick warmup, and should be of sufficient capacity to allow for loss of efficiency with age. The engine temperature should be held to a minimum of 185 F, or provide some other means of obtaining economy of operation and maintenance corresponding to that range.

Most operators hope that solid fuel injection will replace carburetion, if this can be done in such a way as to reduce cost of maintenance. Fuel pumps have too short a life today. The bus industry is anxious to rid itself of the stigma: "Those stinking buses."

The whole problem of crankcase ventilation and other lubrication headaches requires serious work on the part of the bus manufacturer. Considerable progress has been made, but continued effort is needed to improve performance of engines.

Steering continues to be too great an effort for drivers. Road shocks should not be transmitted to the driver. If mechanical improvements can be made, cost need not be excessive. Otherwise, power steering must be adopted.

Riding qualities of city buses must be materially improved. There is room for development in all phases of the vehicle's suspension.

Brakes, air operated equipment, and electrical equipment ed serious engineering thought.

The great changes in design and engineering, which have ted the city bus of today far out of the class of the "jitney" hich preceded it, give all of us confidence that the manufac- ring industries will go far in the next decade to give the merican riding public a better, safer, and a more pleasant de.

INTER-CITY

(cont. from p. 30)

elopment was curtailed during the war, and equipment we re now receiving has about 50% greater cooling capacity an that received prior to the war. We need this capacity, articularly for crossing the deserts in Nevada, for example.

Proper location of baggage space is essential both for the onvenience of the passengers and to reduce costs in baggage andling. We have found under-the-floor space the most esirable both for the convenience of the passenger and for ase of making the transfers at junction points.

In addition to outside or under-the-floor baggage compart- ents, it is necessary to have a parcel rack inside the bus to ake care of coats, hats, small parcels, and small overnight ags.

Speedometers used for the past 10 years are not satisfactory. We do not have the type which is gear-driven from one of the ront spindles, although this statement might be a step in the rong direction.

Accessory units on the bus must be so located as to be easily xchanged and serviced without the waste of labor. Every nove made in developing new buses should be made with his in mind, and that the equipment be more serviceable and s moving parts be built for longer life.

Labor Costs Increase

Labor costs have been one of the material increases in bus peration, and there is no indication that these increased costs re going to be reduced. Therefore, every fraction of a cent, r fraction of a mill, which can be saved in bus operation nust be considered.

We recommend 11:00 x 22 tire size. This size traveled pproximately 10% more miles than did the 11:00 x 20, and he 12:00 x 19, according to our records during the last six months of 1945. The larger size wheel and tire also increases he air space around the brake drum, adding life to brake locks and permitting better braking.

Auxiliary heating units are extremely important. Such quipment would provide hot water circulation through eater units. They should be so arranged as to supplement he water in the powerplant cooling system. Coaches failing etween terminals could be heated if the engine stopped. Quick change in engine temperature is detrimental. This appens when the bus is descending a long grade. A valve operating on a predetermined temperature would circulate hot water through the engine jacket under these circumstances.

An added advantage of an auxiliary heating system would be that buses could be stored out of doors when the temperature is low. Several companies are now working on such equipment, and I am sure a satisfactory product will be offered to bus operators.

Life Requirement

The two million miles of life requirement is not fantastic. Almost every operator in the country has buses which have run a million miles during the war period. All of our diesels which were purchased in 1939 have run more than 1,300,000 miles, and one or two have run more than 1,500,000 miles.

On our long runs west of Omaha we get approximately 200,000 miles per unit a year. A 10-year life is not unreasonable for a bus. A drastic change in design, or a radical development we know nothing of today, might obsolete equipment within a 10-year period, however.

Depreciation on a bus as reflected in our average costs per mile puts the maximum cost at $20,000. On shorter runs, we have buses that cost about $10,000 which have proved to be satisfactory.

I put 19,000 lb as the maximum of overall weight because 37 passengers at 170 lb each, including baggage, reaches the maximum allowance per axle in most of the states. It will take several years before this is revised upward in many of the states.

What the Inter-City Bus Operator Wants

An engine with enough power to permit a bus generally to maintain its position in traffic
Torque converters which will eliminate clutch and transmission as we now think of them
Thirty-seven good seats on seat center spacing of at least 38½ in.
Thirty-five feet overall length of the vehicle
Height approximately the same as now, or about 10 ft. (This can be varied a few inches either way)
Underfloor baggage compartment as a service to passengers and to speed baggage transfer at terminals
Inside parcel rack for further convenience of passengers
Airconditioning equipment to handle temperatures up to 120 F at Baker, Calif.
Two-way radio to speed dispatching and reporting road failures
Speedometer driven off the front wheel
Tire and wheel size of 11:00 x 22
Auxiliary heating system for warming bus and to supplement heat to engine
Sufficient water pump and radiator capacity to cool the engine efficiently at all times
Up to 102 in. width to increase comfort of passengers
All accessory units so located as to permit replacing with minimum labor cost
Styling the bus to increase its appeal to the traveling public

Super-Speed Camer Im
Knoc E

BASED ON A PAPER BY **CEARCY D. MILLER***

KNOCK – plague of engines and perennial subject of research projects – is now yielding its mysteries through the medium of ultra-high-speed pictures taken with a camera designed by Cearcy D. Miller of the National Advisory Committee for Aeronautics. The camera can run at 200,000 frames per sec – a rate that Mr. Miller believes will eventually be increased several times. (A jet propelled airplane, 35-ft long and going 500 mph, would require about 10 min to fly its own length as seen on the motion picture screen if photographed at 200,000 frames per sec.)

A sensational new camera for studying knock takes pictures so fast that a 35-ft object moving 500 mph would take 10 min to fly its own length as seen on a screen where pictures were projected at the normal motion picture rate of 16 per sec.

Knock studies made with the aid of this camera by its inventor, Cearcy D. Miller of the National Advisory Committee for Aeronautics, were the basis of one of the most talked-about SAE papers of the year.

SAE Quarterly Transactions later will carry the complete story of these pioneering studies – how they were made; what they proved.

The accompanying article summarizes very briefly a few of the high spots.

Need for taking pictures so fast arises because the knock reaction occurs in less than 50 microsec (0.000050 sec) and the accompanying detonation wave travels at a velocity of 3000-7000 fps, which is one to two times the speed of sound in the burned gases.

To permit study these photographs are projected on a motion picture screen at the normal rate of 16 per sec; thus the motions seen on the screen are slowed down so that they require 12,500 times as long to occur as they actually did at the time they were photographed. By this process knock appears to be slowed down so that it seems like a disturbanc traveling through burning gases at a rate of 6½ in. per s

Six years' study of high-speed photographs has convince Mr. Miller that knock is actually caused by a detonation wa that follows autoignition of the end gas. (End gas is the pa of the charge that doesn't get burned as a result of the spark In other words, he thinks that a combination of the aut ignition and detonation theories – not either one alone – e plains the phenomenon; that neither autoignition nor a de onation wave is the *sole* cause of knock. (Except two mild types that don't generally cause much trouble: a low-pitche knock, caused by autoignition alone, and a high-pitched typ which appears to be caused by a detonation wave that neither preceded nor followed by autoignition.) His concl sions find substantiation in research results obtained by oth workers.

Similarity in Theories

Explaining his conclusions, Mr. Miller points out tha according to either theory, knock occurs after a period normal combustion when the flame travels from the spar plug through most of the fuel-air mixture. Then a sudde burning of the end gas by autoignition develops the detonatio wave, which is an intense compressive shock wave that orig inates in burning gases and travels at supersonic velocitie through unburned or incompletely burned gases, being pr pelled by the energy released from the burning of each g increment as the wave front reaches it. This intense sho wave sets up vibrations in the gases throughout the combu tion chamber, causing knock.

Actually, he says, the only point of difference between th two theories is in the explanation of what makes all the en gas increments come so close to burning at exactly the sam time as to cause shock – the synchronizing mechanism as it i called. The autoignition theory says that since all end g increments are compressed simultaneously by the norma burning gases, they will reach simultaneously the critical com bination of temperature and density at which they explod The detonation theory, on the other hand, visions the syn chronizing mechanism as an intense, compressive shock wav that travels through the end gas at supersonic velocity. Eac gas increment is probably ignited by the combination of th sudden, intense compression occurring in the shock front, the action of chain carriers in the shock front, and the radiation of heat from the shock front.

Mr. Miller bases his conclusion that knock is caused b

* Paper "The Roles of Detonation Waves and Autoignition in Spark-Ignition Engine Knock As Shown by Photographs Taken at 40,000 and 200,000 Frames per Second," by Mr. Miller, National Advisory Committee for Aeronautics, was presented at SAE Summer Meeting on June 5, 1946.

lms

Engine

oignition followed by a detonation wave on the work of ers as well as on the NACA high-speed photographs that has taken. Other investigators have shown that auto- ition requires much longer than the 50 microsec during ich knock occurs. Autoignition must also be ruled out as sole cause of knock because, in the many laboratory tests which autoignition alone was studied, gas vibrations have er been found. Thus, as Mr. Miller sees it, either a fast m of autoignition must be found (and this appears unlikely this late date in the study of knock) or the occurrence of detonation wave must be accepted.

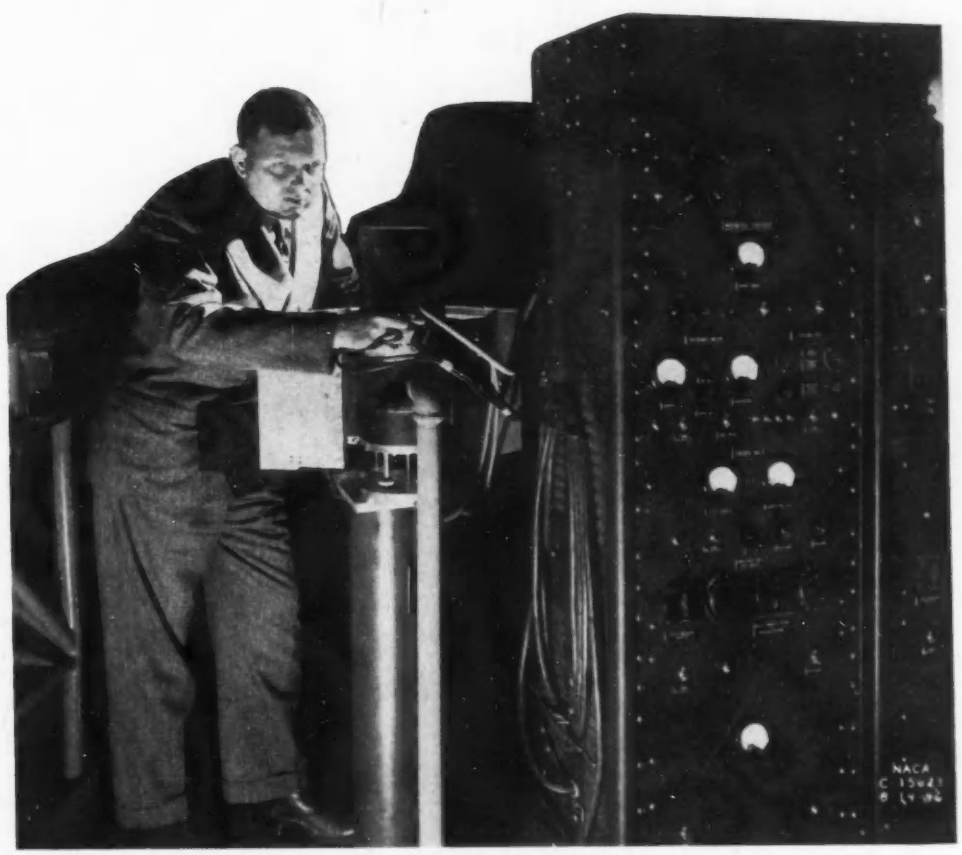
That a detonation wave does actually follow autoignition in knocking combustion is also clearly shown in the high-speed motion pictures taken by Mr. Miller and his fellow NACA investigators.

Two cameras were used to take these pictures. The earlier model, introduced in 1938, was capable of taking 40,000 pictures per sec, and the most recent model, 200,000 pictures per sec, as already mentioned.

Two types of combustion apparatus were used in conjunction with the cameras. The older apparatus in a single-cylinder engine of 5-in. bore and 7-in. stroke, with glass windows in the cylinder head and a glass mirror on the piston top. The newer combustion apparatus was designed to provide a view of the entire combustion chamber. This engine has a bore of 4⅛ in. and a 7-in. stroke. Air for combustion is forced into the cylinder through ports uncovered by the piston at the bottom of its stroke and escapes through other ports on the opposite side of the cylinder. The pressure before the start of compression in this engine is controlled by means of the back pressure applied outside the escape ports.

In carrying out a test to be photographed, the engine was brought up to speed by an electric motor, then it was operated under its own power for but one cycle, and an entire series of photographs was taken during this single combustion cycle. The engine was kept at normal operating temperature by the circulation of heated glycerine in the cooling passages.

Very few shots have been taken with the camera that operates at 200,000 frames per sec because of the oil that quickly spatters its 94 lenses – a defect that Mr. Miller hopes to eliminate soon.



NACA's C. D. Miller standing beside the high speed motion picture camera he devised. Electronic control at extreme right.

POWERIN

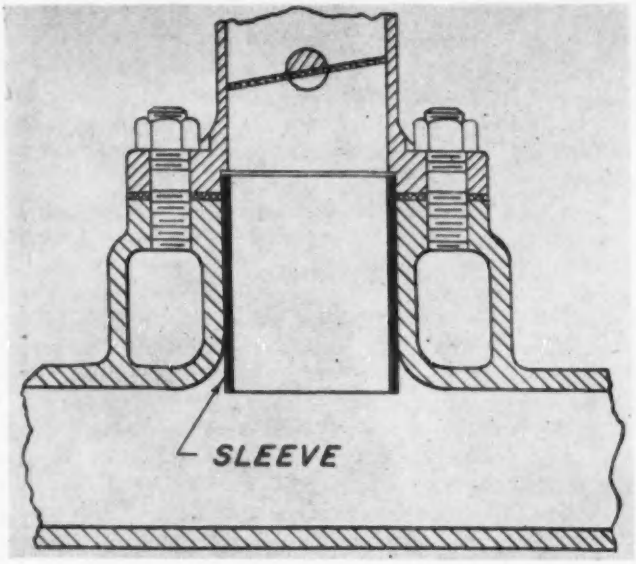


Fig. 1 – Sleeve design to improve distribution

FUTURE engine designs depend on many variables, such as car size and weight, fuel, transmissions, rear-axle ratio, engine location, styling and economics. High fuel tax could be a factor. Above all, a little item "cost" is back with us, and will dominate most decisions. We are entering an inflationary era in which thousands of buyers with fixed income will be driven from the car market unless lower-priced cars are produced for that income group. This will decidedly affect the trend of car design.

Powerplant development can take two trends – constant improvement and change in the conventional engine, or a radical departure in design. In all probability most companies are looking at all conceivable combinations. Engineers realize that any engine must run, day in and day out, in the hands of the public and under widely varying conditions. The remarks immediately following reflect weighted opinion in the industry regarding conventional engines:

Size and Weight of Powerplant

The trend is toward smaller, lighter engines.

Horizontal opposed and V-8 are likely to be favored over long straight eights, due to the added difficulties of higher compression. The four-cylinder engine may reappear, attempting the smoothness of the six with economy of the four. Styling may dictate the opposed type in some cases. It is anticipated that the ratio of engine displacement to car weight will remain about as at present, but with higher specific output per cubic inch. Reduction in size is likely to be gradual. Rpm is linked with power, transmissions and rear axles. Anticipated limit for the near future appears to be 5000 rpm, with some thought being given to somewhat higher speeds. Transmissions will likely cause a downward trend in engine speed. Any reduction in engine weight must *not* be at increased cost. The small, high-speed, European-type engine is not foreseen as having any wide application in this country.

Economy

Economy should be achieved without lowering present performance, and it is linked with many other factors in the vehicle. Opinion indicates that performance is still more important than economy, as the driver may be a 25% fa in economy. In states with high fuel tax, economy rece greater stress, and therefore future tax trend will be a fa With comparatively cheap gasoline and taxes, good econ has not been greatly emphasized, but some hold the opi that within two years economic conditions will force auto bile and engine designs which markedly improve gaso mileage. Some engineers favor improved economy but no a sacrifice in performance – and improved performance, not at the sacrifice of economy. With the express highw visualized for the future, it would not appear logical to re

Mr. Colwell has consulted over 50 leading engineers in passenger car field as to what the future holds in store presents in this article "what cooks" in automobile en trends. Design tendencies for the overall engine as wel those of all components are covered.

He reports, among other things, that cost is still a domi factor in design; that extensive use of light metals, eag awaited by the public, is not around the corner—not as l as light metals cost nearly twice as much as iron or ste

But many engine improvements are well along and sho

high-speed and cruising performance. The public lear during the war that low-speed operation is economical, bu is questionable how long the lesson will last while gasoli cheap. America has always been in a hurry.

Transmissions

Unanimous opinion is that the trend is toward elimina of gear shifts. This is the most active – "hottest" – item in industry. Progress is predicted through the automatic s to the infinitely variable transmission. This would tend reduce engine speed and size, and improve economy by wo ing the engine at high load factor. Passenger cars obtain to 30 ton-miles per gal, whereas buses get from 75 to

uture Cars

CERPTS FROM PAPER

by A. T. COLWELL*

n-miles. Cost again is a factor, and automatic transmissions ll likely be standard equipment on higher-priced cars, op- nal on lower-priced until cost allows their use as standard uipment.

Quote: "An automatic transmission first of all must have automatic starting action whereby no effort of the driver required other than using the accelerator pedal, and it must in a position to deliver the highest tractive effort necessary r starting without manual effort on the part of the driver her than selecting forward or reverse. Such automatic start- g can be accomplished by several means, the particular

ake their appearance in coming models. Compression ratios ill go up; engines will be lighter and smaller. The trend toward better economy, but not at the cost of performance. uel octane number promises to go higher and a transition to eavy duty lubricants is taking place with synthetics entering e picture.

Radical departures from conventional design as represented the Jack & Heintz opposed type slide valve engine and the rosley brazed stampings engine are also described by Mr. olwell.

eans used being related to the rest of the mechanism volved.

"Various degrees of ratio in the transmission can be accom- lished to no extent by the fluid coupling, which is merely a arting device, to much greater extent by a torque converter, nd fully, by sets of gear ratios accomplished either by ountershaft gearing or planetary gearing, and by hydraulic ump devices.

"Complete hydraulic-drive systems are, today, more nearly ossible than ever before due to war-developed high-pressure hydraulic mechanisms. It is of importance to be reasonably efficient in 'top' gear of any mechanism, there being practically no loss in a synchro-mesh gear box in 'top' gear, and efficiency of approximately 99% being obtained with an overdrive. Such a system would allow complete infinitely-variable ratio control which is at least only partially covered by the fluid torque converter."

Use of Light Metals

Light metals will not be used as extensively as the public believes. In many cases the cost is twice that of iron or steel. Where price permits, more aluminum castings will be used, and machining costs do favor aluminum. Aluminum pistons will find wider use, as will rocker-arm brackets and bearings. There is some interest in aluminum blocks and heads. Any trend to air-cooled engines would greatly increase the use of aluminum, with the use of permanent-mold or die castings. If cost allows, die-cast or permanent-mold transmission cases can be used, and it is suggested for water pump impellers and timing gears. Almost unanimous opinion indicates that the cost, high thermal expansion, and low strength will make the wide use of aluminum slower than the public expects, but its use will increase.

Compression Ratio

Compression ratio will go up gradually as fuel is available. Engines must operate on the poorest fuel a driver is likely to use, not on the best he can get. Fuel sensitivity is a problem, particularly in L-head engines. Higher compression will concentrate much attention on engine breathing, with valve-in-head engines likely to be used over 7:1 compression ratio. 8:1 compression seems likely to be the highest over the next few years, although mention is made of as high as 10:1. Engine roughness, or shock, peaks faster than mep with high-compression heads. Increasing compression ratio is a curve of diminishing returns, but its greatest gain is at low load factor, and some increase in compression ratio is likely at once, unless the fuel situation becomes further confused. Many stress the increased cost of higher-octane fuels, and the amount of our oil reserves, intimating that refiners might desire to work toward maximum ton-miles per gallon of crude rather than miles per gallon of gasoline.

The cost and availability of high-octane fuels is not a clear picture. The short-term situation, with a lead shortage, is lowered-octane fuel, with 80 maximum. How long this will continue is an economic and political question; and many mention the uncertainty of our oil reserves as a reason for less high-octane fuels, thereby increasing yield from crude oil. The general opinion is, however, discounting the short-term outlook, that octane number will go higher, gradually. The motor designer must know what fuels will be generally available to design intelligently.

The entire situation is somewhat like the student who said to his teacher: "I have added this column of figures ten times, and here are the ten answers."

Advances in Carburetion

No radical changes are expected in carburetion, but research work is going forward. Less manifold heat, improved accelerator-starter switches and automatic chokes would be desirable. Elbow air horns may be used to reduce over-all height, and perhaps side outlet carburetors to accommodate lower hoods. Alignment of the carburetor with the intake

* Paper "Powering Our Future Cars," by A. T. Colwell, Thompson Products, Inc., was presented at Detroit Section, May 20, 1946.

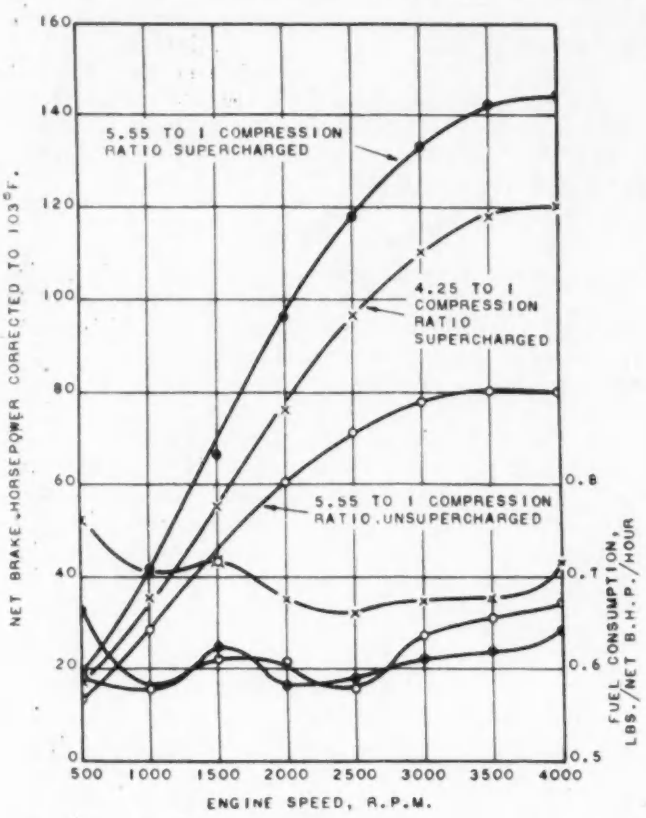


Fig. 2 – Comparison of results obtained by supercharging a 233 cu in. engine as against unsupercharged performance of the same engine

manifold, and the manifold with the block will receive attention to aid distribution. Fig. 1 shows an experimental sleeve design which helped distribution. More uniform heat at intake ports would be desirable, and a number of minor carburetor shortcomings might be corrected by slightly more expensive design. It would be desirable to have the carburetor remain in the same condition as when installed for a longer time. More than one carburetor pays off on power.

Fuel System

There is much opinion that the fuel pump belongs in the gas tank as a booster pump to prevent vapor lock. Aircraft used a booster pump at the tank to pressurize the line and expel vapor and air from the fuel, passing only liquid to the line. A fuel pump at the engine was also used, but automobile practice would contemplate only the one pump at the tank. Automobile fuels are considerably more volatile than aviation fuels, having Reid vapor pressure of 11 to 14 lb, as against about 7 lb for aircraft fuel.

Fuel Injection

Opinion is practically unanimous that fuel injection equipment is too expensive, but would be used at affordable cost. Some engineers feel that cost will be reduced and injection used for better distribution, some economy and use of slightly lower-octane fuel.

Combustion-Chamber Design

Improvements will be made in combustion-chamber design and the entire induction system. The spherical chamber hold interest, and the F-head receives considerable favorable com ment. Design will point toward anti-detonation and anti shock. Alex Taub recommends two spark plugs in L-hea engines, one near the exhaust and one near the enlarge throat.

Many opinions state that above 7:1 the valve-in-head desig is likely to be used. Sleeve valve or slide valve designs a mentioned, with the difficulty of starting in extremely col weather.

Axle Ratio

The ratio of engine speed to car speed is likely to decrea This is practical with the overdrive or by transmission desig cost being a factor in each case.

Engine Speeds

There is a present tendency to increase engine speed slightly, with about 5000 rpm likely to be a peak for th immediate future. Naturally, thought is probably being give to somewhat higher speeds in small sizes. Higher speeds ma allow a smaller engine, but give lower mechanical efficienc and are noisier. Future transmission development will prob ably tend to lower rpm.

Performance

The public will demand that performance be not less tha 1942 cars. The need for any higher performance is question able, as larger cars do 90 mph and accelerate in top gear abou 3.3 ft per sec. Higher performance increases engineering problems with little return. Perhaps a reduction in "get away" might be accepted in exchange for convenience and smoothness with future transmission systems. Preponderant opinion is that whatever changes are made, they should no sacrifice present performance.

Displacement

The ratio of displacement to weight of car is likely t remain nearly constant. Horsepower per cubic inch will tend to go up.

Supercharging

Cost again is the important factor. Immediate general use

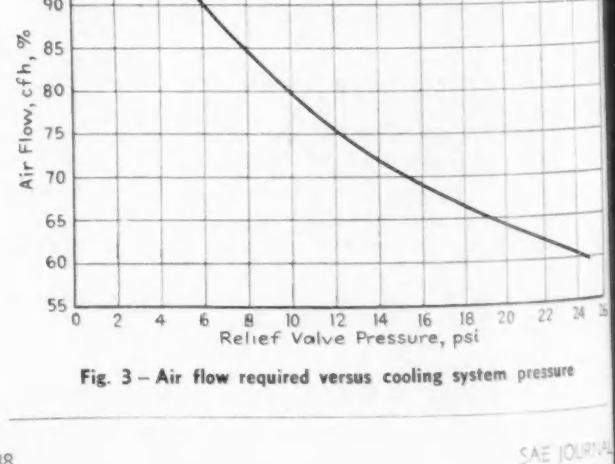


Fig. 3 – Air flow required versus cooling system pressure

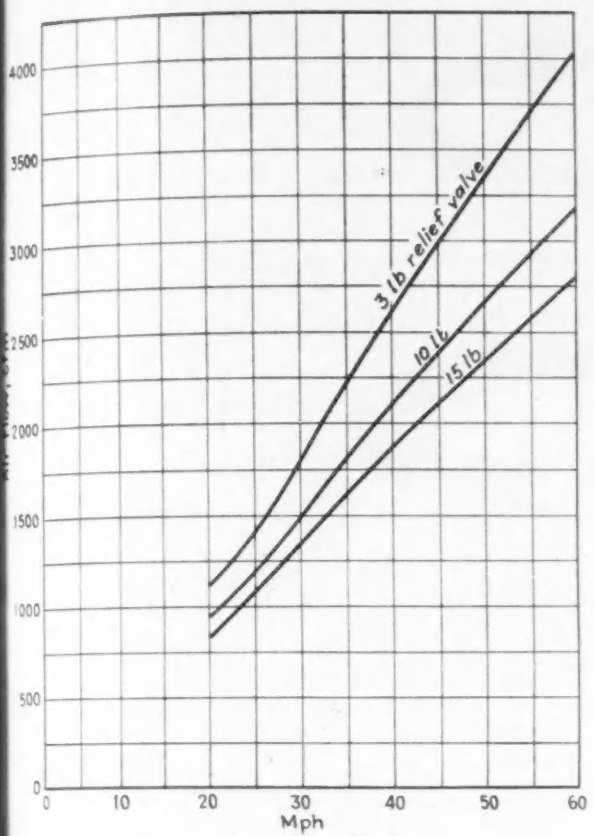


Fig. 4 (left) – Air flow required versus vehicle speed

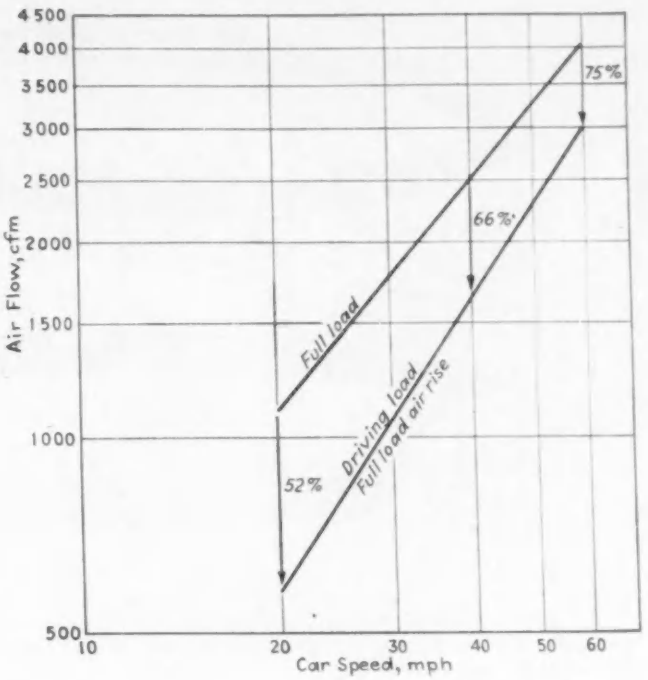


Fig. 5 (above) – Air flow required at full load and part load

supercharging is not foreseen, although many believe esearch will be done, particularly on small, low-cost super-harging on the turbo principle, possibly with water injection. ngenious application might apply it where space is limited. Should supercharging be used for mechanical drive, the positive-displacement type is preferred, but for turbo drive, he exhaust-gate controlled centrifugal would find favor. Noise is a factor, but supercharging is technically preferable o increase in compression ratio. "It cannot be justified on he basis of higher speeds, but must demonstrate itself in conomy and lively performance in the middle and useful anges." It is an expensive way of getting the equivalent of igher displacement, but is technically attractive for operating he engine at high load factor, cutting in as an auxiliary ower source when needed. Power can be raised 50%, thus llowing a smaller engine, and possibly better fuel economy. his saving can only be realized with a "torque-converting" ransmission, the equivalent of an electrical generator-motor ystem, weight not to offset the engine-weight saving.

Fig. 2 shows results of a recent test of supercharging.

Cooling System

There is a decided trend toward pressurized cooling sys-ems, which are in limited use now. A completely sealed ooling system with factory-installed year-around coolant, would be attractive if cost is not too high. Such a system would allow quicker warm-up, help eliminate pockets, allow smaller radiator, but would necessitate slightly higher-octane fuel. Integral mounting of the engine and cooling ystem with no flexible joints is considered a possibility. Distilled water with a rust inhibitor could be used in non-freezing weather. High pressures would call for much better plumbing. Up to seven pounds pressure is in present use with excel-

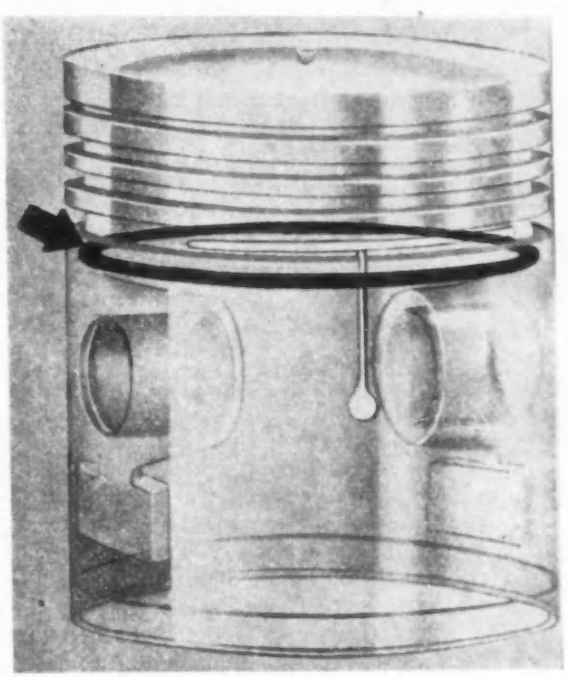


Fig. 6 – Belted piston provides expansion control

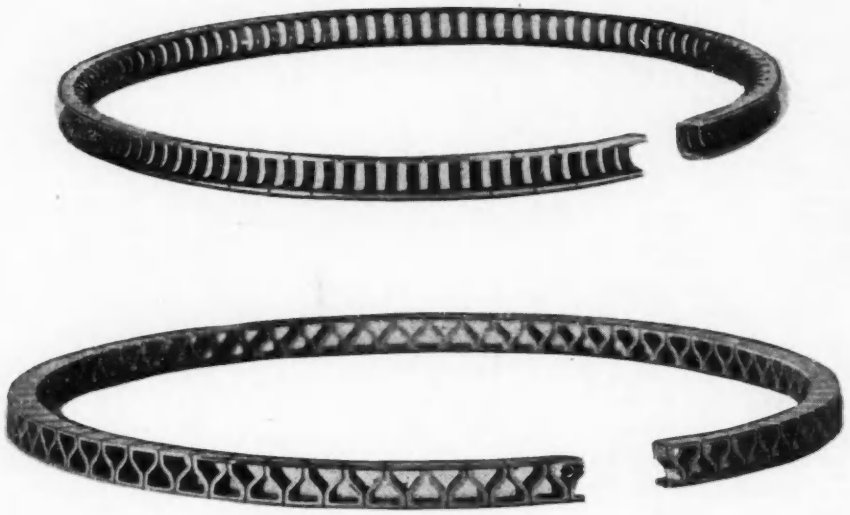


Fig. 7 – Flexible oil rings. Upper ring is the U-Flex type and lower ring is the Z-Flex type

lent results, and stretches out cooling capacity without adding to radiator or fan.

Quoting: "The trend has been toward cooling systems operating at pressures slightly above atmospheric to those in excess of 10 lb per sq in. gage. As more and more demands are continuously being made on the cooling system in the interest of styling, the industry has been forced to develop units which would operate satisfactorily at elevated temperatures and pressures. Less air is needed by the radiator to strike a heat balance. Fig. 3 shows that at 15 lb pressure, air flow has been reduced to 71%. Fig. 4 shows the variation in radiator air consumption at different speeds in mph with change in cooling system pressures, under full-load conditions. The greatest difference occurs at high speeds, indicating a reduction in air horsepower required.

"The two curves shown on Fig. 5 are those for the radiator air flow at full load and part load, the latter curve representing the volume of air required to handle the heat rejected to the jacket at car driving load – assuming the same air temperature rise across the radiator is that obtained under the full-load conditions. A method of controlling the fan speed or pitch of the fan blade will be necessary to obtain this condition.

"With higher operating pressures, methods of assembling radiators, other than by the soft solder method, may be necessary."

Bearings

Steel-backed, copper-lead bearings with 0.001 plating will be particularly satisfactory should the trend be toward automatic transmissions, larger bores, shorter strokes, and high explosion pressures. These bearings will handle 3000 lb per sq in., operating at 4500 to 5000 rpm. The coating would be approximately 92% lead, 7% tin, 1% copper. The use of the aircraft silver bearing is not foreseen because of cost, but such bearings are good for 7000 lb per sq in. pressure. The use of hardened journals, improved lubrication, better filtration and cooling will come before high outputs can come with a minimum of trouble. Compounded oils will help the corrosion problem. Aluminum-faced, steel-backed bearings are a future prospect when bonding is perfected, and are particularly good against corrosion. Solid aluminum bearings are used in heavy-duty engines with high pressures where the wall section can be heavy, clearance comparatively high, and speeds low.

Hardened Bores

General opinion is that hardened bores are not entirely justified in the passenger car field, but may be used if increased hardness can be obtained without a major increase in cost, such as by localized hardness.

Thompson Products is hardening alloy iron cylinder liners in an automatic conveyor system by Austempering to a hardness of 490 to 510 Brinell hardness. This method of heat treating is distinguished from ordinary hardening operations in that the desired hardness is achieved upon direct quench without resort to tempering or drawing to reduce a higher water or oil-quenched hardness. The advantages of the method are a great reduction in distortion and superior physical qualities. The operator places soft sleeves on a conveyor and removes clean hardened sleeves after the cycle. Four-in. diameter sleeves are held to within 0.006 total indicator reading, which is far less than by previous methods.

Copper plating the OD of dry sleeves improves heat conduction, but is expensive.

Pistons

Aluminum pistons will find wider use, with much interest in expansion control – as provided for in the belted piston of Fig. 6. Some may be shorter in length to save weight. Ring grooves will be narrower and deeper, wider lands for better ring support, and perhaps somewhat wider head lands to reduce top ring temperatures. Oil cooling may be tried, similar to heavy-duty operation. Some design changes may be expected in castiron pistons in an attempt to continue their use. For extreme operation, the forged aluminum piston may be considered for better heat dissipation and physical properties.

Piston Rings

Opinions vary – some feel rings are entirely satisfactory, be

general opinion is that improvements must be made. Anti-scuff and anti-wear coatings have helped.

Quoting Ralph Teetor: "Piston rings will, for a time at least, be of the same general type that has been used. The trend is in the use of more narrow compression rings, 3/32 in. and 5/64 in. Experience with chrome plate on the face of rings has been very good, their increased use depending on decreasing the cost, which has been five to eight times that of the unplated ring."

Oil-ring design change will be toward elimination of clogging and retention of peak performance for a longer period. Some feel that the proper place for chrome is on the cylinder bore in preference to the rings, but cost is high. New designs of steel oil rings are proving of considerable interest. Fig. 7, U-Flex ring and Z-Flex ring. The polar diagrams of these rings are practically circles.

Spark Plugs

Spark plugs are quite satisfactory, but must be improved against fouling and cracking for any increase in pressures. Missing has been caused by relatively low resistance path parallel to the plug gap caused by deposits. Tendency is not seen to go below the 14-mm plug, but 10-mm insulator in a 14-mm shell may be a good approach. Built-in suppressors may be needed for short-wave radio, and the trend is toward alumina as an insulator.

Lubricants

A transition to heavy-duty lubricants is taking place, the eventual lubricant visualized as entirely synthetic of greatly improved characteristics, but general use is probably some time away. Future engines will stress lubricating oil more severely as to oxidation, sludge and varnish deposition, and wear resistance.

Synthetics so far have poorer lubricating or "oiliness" properties, and the cost is high, but they are subject to less viscosity change. It is likely that the near future will see a

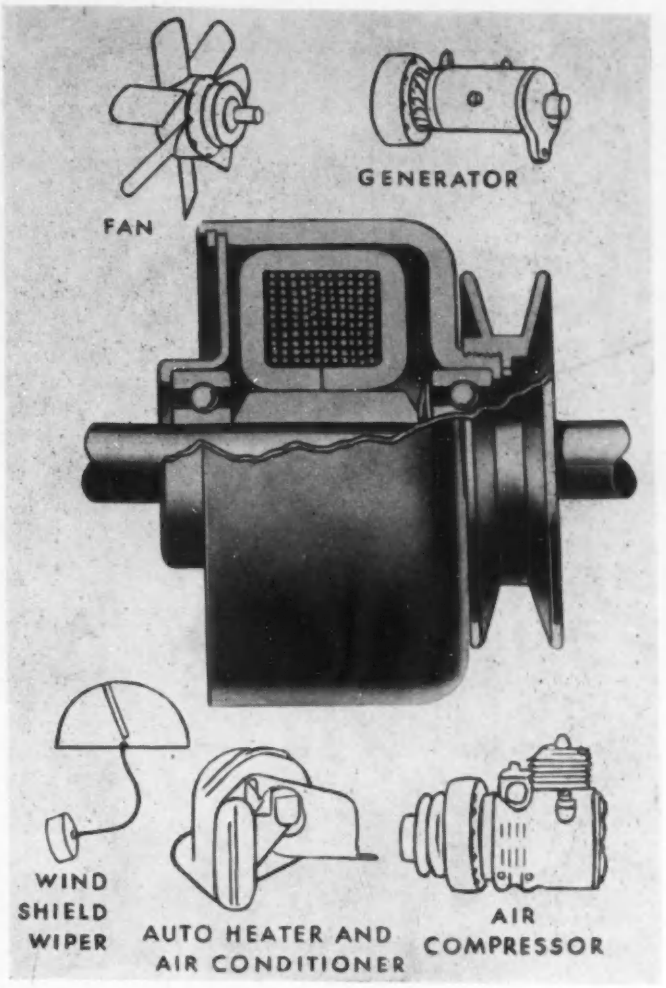


Fig. 8 – Eddy-current fan drive is offered as a solution to the air-cooled engine

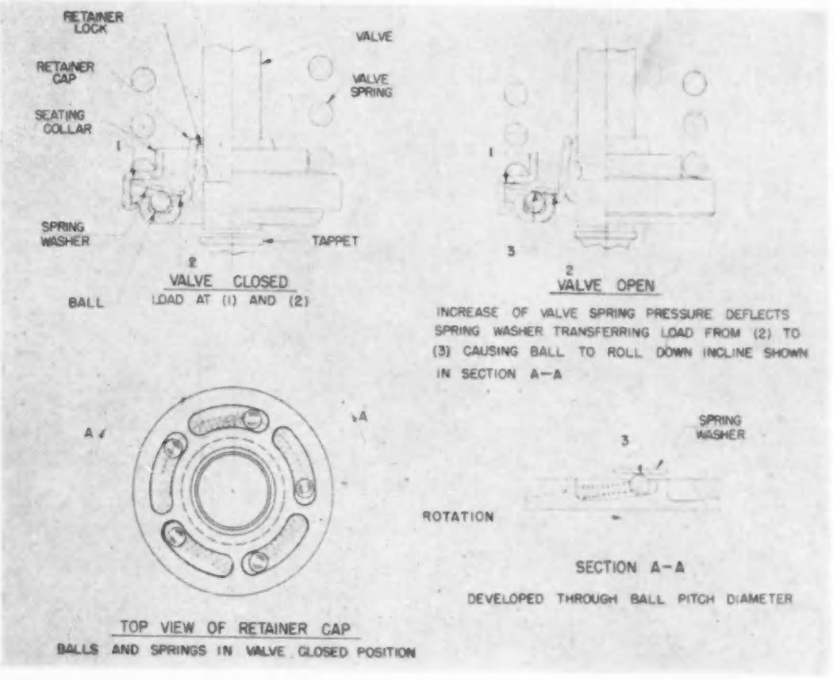


Fig. 9 – Valve rotator cleans valve face and is reported to increase valve life.

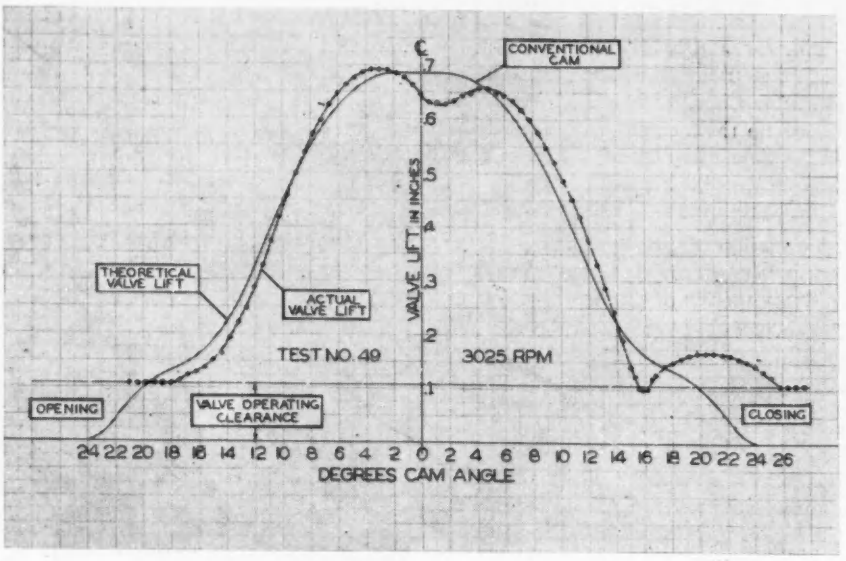

CONVENTIONAL CAM
THEORETICAL VALVE LIFT
ACTUAL VALVE LIFT
VALVE LIFT IN INCHES
TEST NO. 49
3025 RPM
OPENING
VALVE OPERATING CLEARANCE
CLOSING
24 22 20 18 16 14 12 10 8 6 4 2 0 2 4 6 8 10 12 14 16 18 20 22 24 26
DEGREES CAM ANGLE

Fig. 10 – Valve motion study showing bad jumping

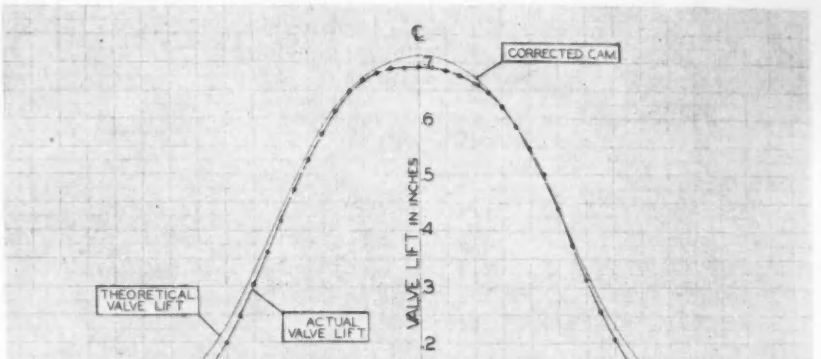

CORRECTED CAM
THEORETICAL VALVE LIFT
ACTUAL VALVE LIFT
VALVE LIFT IN INCHES
TEST NO. 68
3200 RPM
OPENING
VALVE OPERATING CLEARANCE
CLOSING
24 22 20 18 16 14 12 10 8 6 4 2 0 2 4 6 8 10 12 14 16 18 20 22 24
DEGREES CAM ANGLE

Fig. 11 – Study shows perfect valve opening and closing in corrected cam design

combination of petroleum and a chemical synthetic combined to achieve better viscosity, pour, and cleanliness.

Engine in Rear

Opinion is mixed, but in general the rear-engine car is not favored. Those opposed see no reason for exchanging engine and luggage space, at the same time adding a weight-balance, cooling, dirt, remote-control and interior-heating problem. The design is now virtually obsolete in Europe.

Proponents visualize a lighter engine, possibly air-cooled, shorter drive, less noise, less heat to occupants, a roomier car, a lower floor, and better visibility. The horizontal opposed powerplant is favored.

Air-Cooled Engines

Opinion is that liquid cooling is likely to persist, but air cooling may be used for extremely small cars. Air-cooled engines are more expensive, the estimate being about 25%, and are noisier. Collection of dirt on fins affecting cooling is mentioned, as well as power absorbed by the cooling fan. Adequate cooling fins appear to be a problem, and liquid-cooled block-design tends toward greater smoothness.

Air cooling also has proponents. Quoting Vincent Young: "Air cooling offers many advantages, and with eddy-current fan drives, Fig. 8, there is no good reason why cooling should be a problem, as this type of drive can be designed to deliver an adequate supply of cooling air at the lower speeds without excessive power losses at the high end."

Other Trends

In improving conventional engines there is great interest in the following items:

- Sodium-cooled valves for longer valve life, better performance and reduced maintenance – both drilled stem and hollow head;
- Valve rotators, shown in Fig. 9, which continually clean

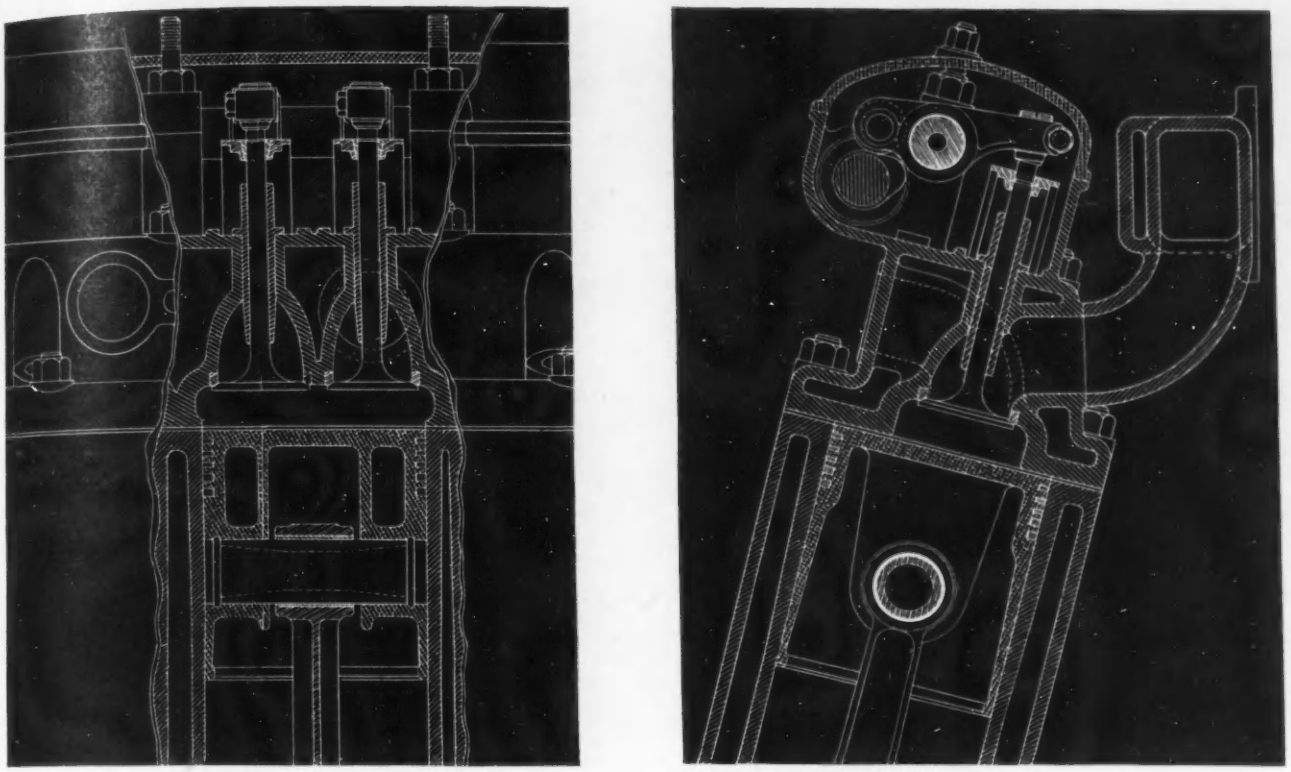


Fig. 12 – Sections through Fageol Twin Coach engine

the valve face and block seat, help to prevent guide sticking by cutting away stem deposits, and extend valve life where distortion is present;

• Automatic tappets, or valve clearance regulators, which give better valve timing, improved dynamic action and reduced maintenance;

• Improved camshaft design, giving good valve dynamics. A new method, giving excellent results, has been evolved.

Quoting H. H. Engemann: "Calculated theoretical velocities and accelerations do not exist at the valve because of flexibility in the system. A correctly designed cam, properly tailored to the timing requirements, stiffness, and mass of the valve gear and gas pressures, is the key to correct valve dynamics. It is not possible to obtain optimum valve dynamics without some type of clearance regulator. A new method predicts within negligible error the valve motion, by expressing the whole cam contour, including all necessary corrections, as a continuous equation. A camera of 8000 frames per sec is used in the work, photographing a vernier scale attached to the valve, using a strobolux and other accessories." In the illustrations, the solid curve is the theoretical valve motion considering the whole system rigid and operating with zero

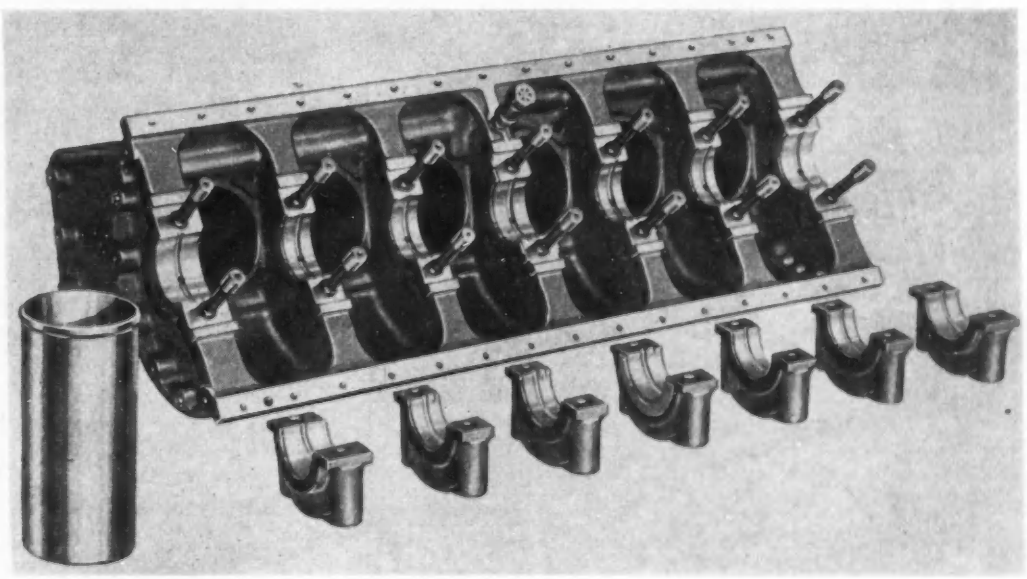


Fig. 13 – Cylinder block of the Fageol Twin Coach engine

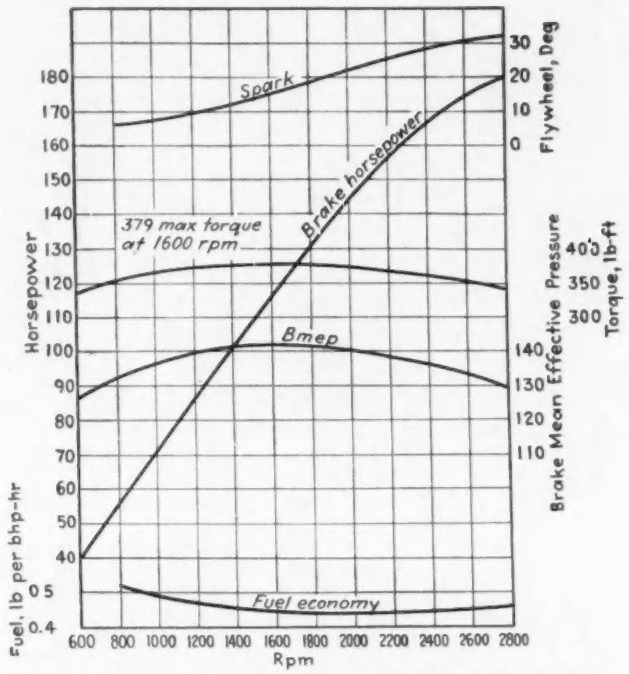


Fig. 14 – Performance curves for the Fageol Twin Coach engine

clearance. The line drawn through the small circles is the actual valve motion, plotted from the high-speed film.

Indicated in Fig. 10, at 3025 rpm, is bad jumping; valve hits seat at 15 ft per sec, bounces 1/16 in., hits again at 5 ft per sec.

In Fig. 11, corrected cam design without any other changes shows perfect opening and closing of the valve. The solid line is the cam which was computed to give the actual valve motion obtained. The desired valve motion selected as the basis for the cam computation varied less than .001 from the actual valve lift obtained, and therefore is not plotted on the figure.

This method is proving of interest to the industry.

As regards induction hardening and high-frequency induction brazing, W. C. Dunn says: "Where large diesel engines use a great deal of welding, it is now possible to use high-frequency induction brazing to assemble the fabricated parts and thereby obtain a very strong, light-weight, exact product at a low cost. Also, present practice – for heavy duty – has been developed to the point where normalized crankshafts are now used after induction hardening, resulting in bearing surface hardness of about 52 Rockwell C. In connection with aluminum-surface bearings, for example, this has resulted in extending the life per unit of wear as much as ten times. Modifications of this practice may readily be applied to passenger-car design, resulting in higher permissible bearing loads and speeds than in the past, and possible use of smaller diameters and lighter crankshafts."

The Fageol Twin Coach engine combines many good features from racing engines in a conventional engine to produce fine results. The following information is submitted by Mr. Louis J. Fageol, President:

"A great many features being used in various designs have been incorporated with a patented combustion chamber, compression ratio 7.3:1, operating on 73 to 85-octane fuel. Fig. 12 shows sections through the engine, Fig. 13 the cylinder block, and Fig. 14 curves for the engine. Although this is a heavy-

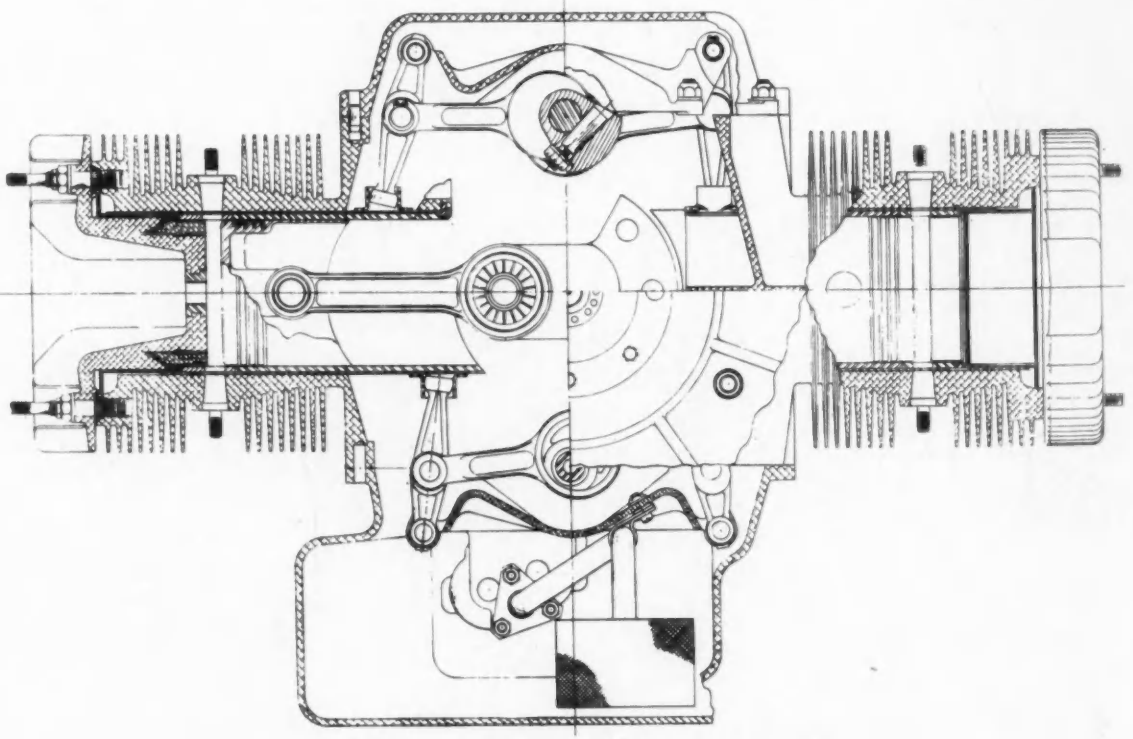


Fig. 15 – Section through Jack & Heintz engine

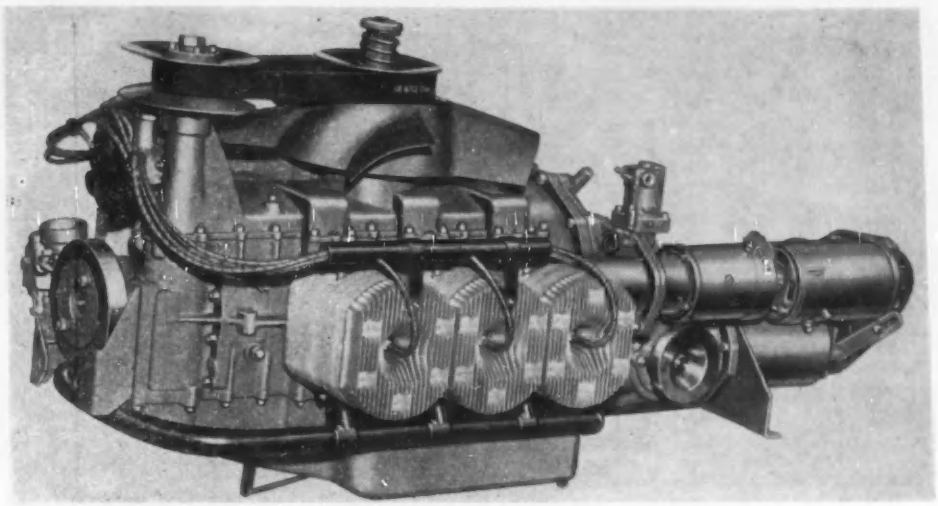


Fig. 16 – Jack & Heintz engine

duty engine, it indicates what can be done. It has a large water pump; oil is held within 15 deg of water temperature. There are full and unobstructed water passages in and around all points of the cylinder bores for their entire length. Maximum variation in temperature is 4 deg, cutting down distortion and its attendant troubles. Water has clear passages around all valve seats, combustion chamber, intake and exhaust ports. Water from the outlet heats the manifold, holding its temperature uniform – a variation of 25 to 30 deg can result in a power loss exceeding 10%.

"The combustion chamber is designed with uniform wall thickness, and is of small size in relation to the engine cylinder. Area of the piston head exposed to the force of explosion is reduced one-third, the full force being exerted after the piston has passed top center by gradually expanding out of the combustion chamber. The spark plug is placed near the exhaust valve, and the narrow combustion chamber gives short flame travel. Cylinder sleeves are a slip fit in the bore, with clearance of .001-.002. The specific fuel consumption is .44 at 2000 rpm; bmep is 141 at 1600 rpm; hp per cu in. is .445, and weight 4.7 lb per bhp."

Departure from Conventional Design

Two designs departing from the conventional are submitted herewith – the Jack and Heintz and the Crosley engines. Messrs. Ralph Heintz and Richard Owens supplied the following data:

"The engine can be made in two, four or six cylinders, liquid- or air-cooled, the air-cooled being largely fabricated of die-cast aluminum or magnesium alloys."

Fig. 15 shows a section through the engine and Fig. 16 shows the complete engine.

"It is the horizontal opposed type with slide valves. The crankshaft is of the built-up type, bearing alloy bonded directly to the crank pins for better cooling, and the bearings are not split. Pistons are forged aluminum, slide valves are formed Nitralloy sheet, running at one-quarter engine speed, and cylinder liners are alloy iron. The compression ratio is 8.5:1, and cooling is by an axial flow fan, belt driven, with variable speed sheaves. The engine has been designed for either front or rear installation, and weight of the six-cylinder engine, ready for installation, is 245 lb. The combustion chamber is bounded by two flat surfaces and the ID of a cylinder, which eliminates any sharp changes in section. The two engine halves are identical and contain one bank of cylinders and half a crankcase.

"Reference to the curves in Fig. 17 will show the power, torque, and fuel consumption characteristics of the engine. The use of 18 die castings of seven different designs is an interesting feature of the engine."

Several engineers mentioned this engine as an interesting

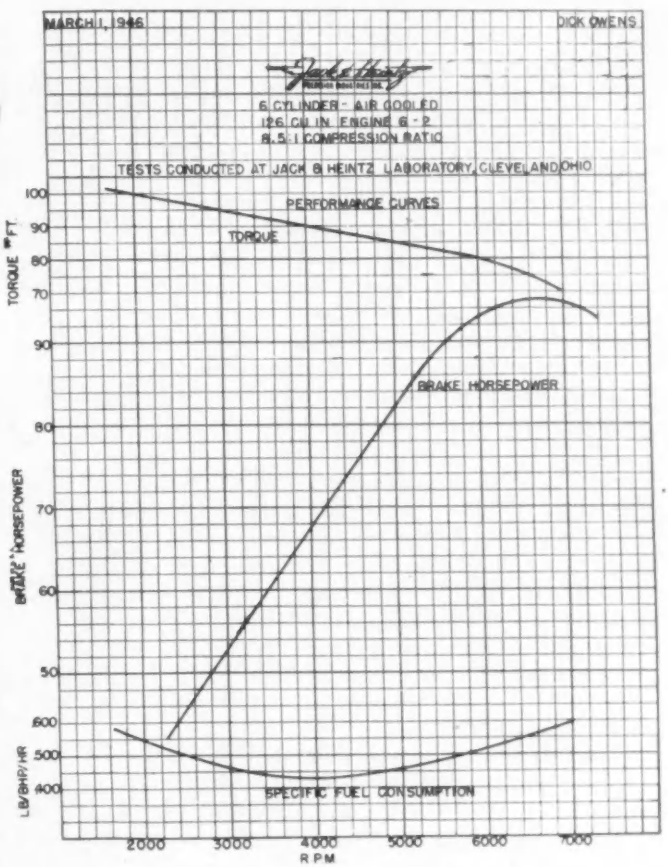


Fig. 17 – Performance curves for the Jack & Heintz 6-cylinder engine

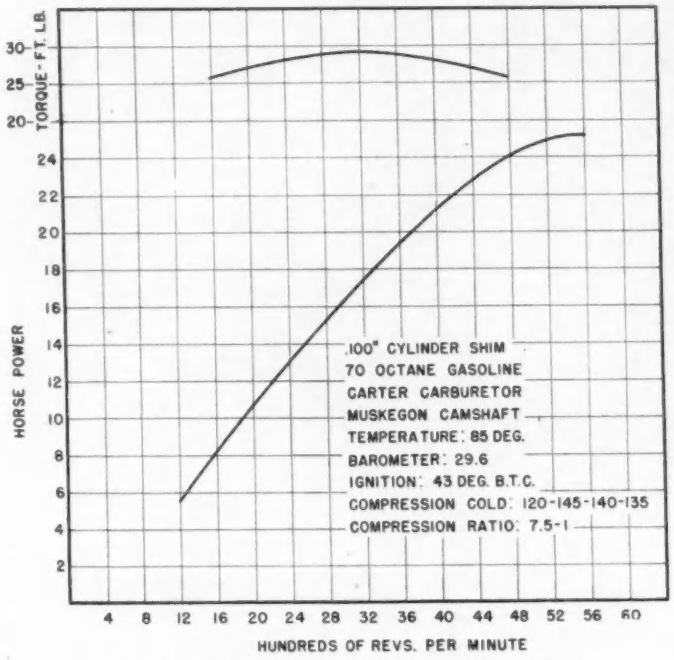


Fig. 18 – Performance curves for the Crosley engine

departure in design, and hol l the opinion that an air-cooled engine could be satisfactorily used.

The Crosley Engine

The following information was supplied by Mr. Powel Crosley:

"The Crosley engine was developed as a light generating set for Navy aircraft use. The engine is unique in that the block is made of steel and stampings brazed together, the idea being a light-weight, high-compression, high-speed, economical engine, due to thin walls, and consequently a cooler firing chamber. The four-cylinder automobile engine has displacement of 44 cu in., and develops 26.5 hp at 5200 rpm, as shown in Fig. 18. Weight of the engine with accessories is about 121 lb. There are about 125 stampings for the four-cylinder block shown in Fig. 19.

"Cylinder walls and valve seat inserts are hardened from the heat of the brazing operation. The cylinders are made of light-walled alloy tubing, while the cylinder heads, intake and exhaust ports, valve cases and water jackets are made of 20-gage stampings. The parts are held in place by press fits, spot weld or crimping operations before copper-hydrogen brazing. Warpage is held to about 1/64 in. in 16 in., and only ½ lb of metal is removed in machining the block. The interior of the water jacket is covered with a clear, hard coat of plastic. There is an overhead camshaft. Crankshaft pulley, fan assembly, fan pulley, water pump impeller and pulley are made from copper-hydrogen-brazed stampings. The crankcase is an aluminum casting.

"In a 1200-lb experimental car, 250 lb payload, fifty mpg was obtained at 55 mph. At maximum torque, specific fuel consumption is 0.48 per hp hr with compression ratio of 7.5:1. Compression ratios of 9:1 have been successfully employed."

This engine construction has caused considerable interest, due to the fact that the exact interior construction can be known and is not subject to the non-uniform wall thicknesses and other difficulties of casting. The engine is apparently good at high compression ratio. The induction brazing process of making sub-assemblies should decrease distortion in the block. The writer has no data on cost, but the low engine weight has caused comment on its use for rear-engine designs.

Ten to Twenty Years Ahead

No mention was made of atomic-powered engines. Looking ahead ten to twenty years, the following thought was expressed: "We can look forward to engines that will be about 1/3 the size of the present engine and ¼ the weight. Probably they will be of the turbo type, using low-grade fuels. The spark plugs will be of a new type suitable for this design of engine. There will be great use of aluminum and magnesium in the parts not subjected to heat, and of course the engine will be air-cooled. Transmissions will be of the hydraulic pump type with variable stroke. As the turbo type engine will use continuous combustion, the fuel will be injected and the carburetor will be of an entirely new design. The design of the engine eliminates a great many things which we now have, such as pistons, piston rings, hardened bores; and will replace them with other sources of trouble which will give us an entirely new field of development" – a comforting thought.

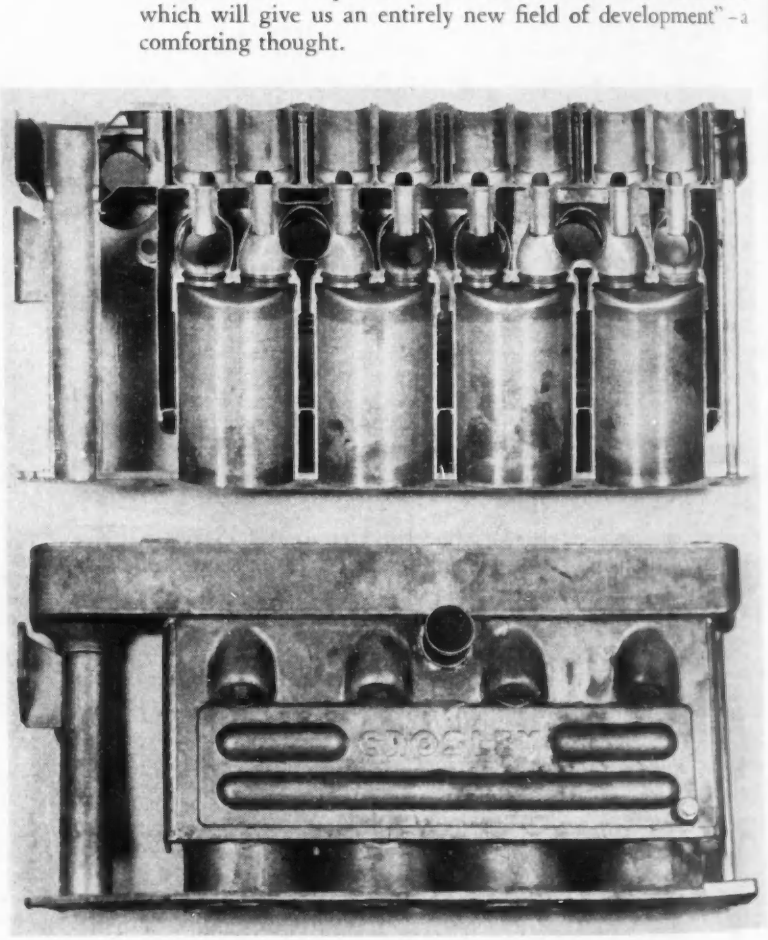


Fig. 19 – Cylinder block of the Crosley engine

Radical Bearing Theory Says

Load-Carrying Capacity Equals K(2xLoad rpm - Journal rpm)

From a paper by **J. M. STONE** and **A. F. UNDERWOOD***

LUBRICATION difficulties encountered with automotive engine journal bearings may at long last be eliminated, thanks to a new concept on bearing performance advanced by Messrs. Stone and Underwood. They have brushed aside the dust of dogma in old bearing theories to preview a fresh and apparently sounder explanation of bearing behavior.

Considered in this paper, later to be presented in full in *SAE Quarterly Transactions,* are dynamically loaded bearings. This type of bearing has been long neglected in practical engineering, although it represents the most important bearings in aircraft and automobile engines – wrist pin, crankshaft, and connecting rod bearings.

Bearing experts, commenting on the paper at the time of its presentation, hailed this work as a most important contribution which promises to revolutionize bearing design. They reported that its stimulating effect has permeated all quarters. Engineers in industry, professors in universities, and technicians in research centers are enthusiastically investigating its possibilities and practical applications.

What is this "sesame" which is to open new vistas for the designer? It is embodied in one simple formula which says:

Load-carrying capacity = K(2xLoad rpm – Journal rpm)

The factor K for a given bearing depends on the length, diameter, clearance, oil film thickness, and oil viscosity.

Basis for the formula is the accepted fact that the load which a journal bearing will support is dependent on the minimum thickness of the film generated between the bearing surface and journal. (Factors governing the thickness of this essential oil film will be fully described in *SAE Quarterly Transactions.*)

Application of the formula to the various bearing configurations reveals interesting and, perhaps, disconcerting information to believers in the conventional. For example, in an arrangement where the load rpm is half the journal rpm, the formula would indicate the load-carrying capacity of the bearing to be zero. In that case, the oil film would not develop and the journal and bearing would run with metal-to-metal contact. Laboratory tests have confirmed this formula result.

Engineers have used floating bushings between journal and bearing support, believing improved load-carrying capacity to result. Fallacy of this thinking is indicated by the formula. Even an ordinary bearing has twice the load capacity of this arrangement, the formula says. It tells the engineer that optimum results will be obtained by restraining the floating bushing from rotating. A well-designed bearing has been proved in practice to have load-carrying ability equivalent to the floating bushing, confirming the mathematical conclusion.

The formula also tells what conditions make for a high capacity bearing. If the load and journal rotations are in opposite directions, the formula says their effect will be additive. Therefore, at any given load, it would appear that bearing capacity continually increases with journal speeds in the opposite direction.

The authors set out to derive theoretically the fundamental relation giving the load-carrying capacity of journal bearings and developed postulates wherein vectorial integrations and similar operations are wrapped up in a neat package of differential equations.

To satisfy the query "But will it work?", validity of the mathematical conclusions has been demonstrated in the laboratory. A set-up was constructed that shows the effect of journal and load speed.

Measuring the oil film thickness was ingeniously accomplished by inserting a small pin through the side of the bearing block to ride lightly against the journal surface. The pin moves in and out as the oil film thickness between the journal and bearing varies. By connecting the pin to an electrical circuit, variation in oil film thickness at the pin is recorded on an oscillograph screen. Photographs of the oscillograph screen show exactly the status of the oil film for a particular set of operating conditions. Confirmed by this technique were the results predicted by the formula.

Turning from laboratory tests to problems of the engine builder, the authors discuss a method for investigating capacity of engine bearings subjected to dynamic loads. They show that the capacity of a connecting rod bearing varies from zero to ten times the load which a unidirectional bearing will withstand.

No pretense is made that this work is the final answer to all bearing ills. Mathematical and experimental work remains to be done in determining load capacity of a bearing on which a high force is applied for a short portion of the cycle. Typical is the gas explosion imposed on a connecting rod bearing, squeezing the oil film. This work does provide a tool for the designer to pry open the door to journal bearing behavior.

*Paper entitled "Load-Carrying Capacity of Journal Bearings," by J. M. Stone and A. F. Underwood, Research Laboratories Division, General Motors Corp., was presented at SAE Summer Meeting, June 6, 1946.

USERS, DESIGNERS PROBE FU
At Transportation & Maintenance Me

BY DAN CHENEY
Field Editor, Northwest Section

DISSECTING the economics of bus and truck operations, speakers agreed at the SAE National West Coast Transportation & Maintenance Meeting, Aug. 22 to 24 in Seattle, that:

- Improved methods of performing maintenance work in view of ever-increasing man-hour costs, and
- Improved economy through design must be built into the equipment of tomorrow.

More than 300 engineers registered to find out latest techniques and opinions in order to better their services, as well as to hold to a minimum rising costs of fleet operations. Several speakers alluded to the fact that the bus industry is only about 30 years old, despite its great size and important stature in the nation's system of transport.

General Chairman W. W. Churchill and Co-chairman Lee Ketchum developed a far-seeing schedule of technical topics. The Northwest Section of the Society was host, and the meeting was welcomed by Councilman Mike Mitchell of Seattle in behalf of the mayor.

SAE President L. Ray Buckendale spoke at the concluding banquet, when a barometer was presented to E. F. Lowe, who retires from SAE staff service as assistant general manager after 12 years in that post. SAE General Manager John A. C. Warner also attended the meeting.

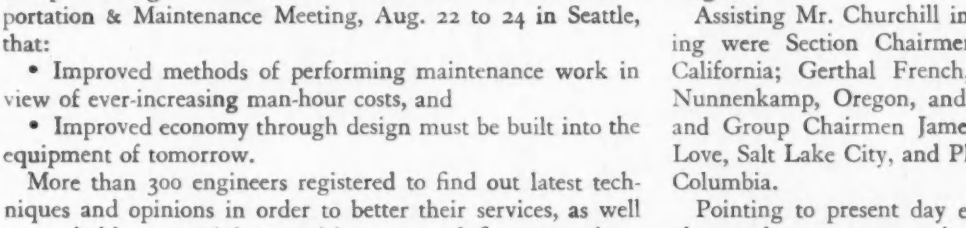
Technical topics during the meeting covered development and operating problems of trucks, buses, fuels and engines, bearings and lubricants, automatic transmissions, and passenger cars.

Assisting Mr. Churchill in planning and staging the meeting were Section Chairmen Trescott S. White, Northern California; Gerthal French, Southern California; William Nunnenkamp, Oregon, and D. D. Thomasson, Northwest, and Group Chairmen James H. Ray, Spokane; Leonard J. Love, Salt Lake City, and Phil J. Schrodt, Vancouver, British Columbia.

Pointing to present day equipment as a far cry from the elongated passenger car chassis used 30 years ago when bus transportation began to emerge into an industry, J. M. Shoemaker discussed in detail how improved performance can be designed into the heavy duty powerplants of tomorrow. Such engines, the International Harvester Co. engineer predicted, could have a service life without breakdown or major overhaul of 100,000 miles.

He sees in the laboratories of the petroleum refining companies some of the answers to present barriers. Unheard of molecular combinations are commonplace, and more are being compounded all the time. Refining processes will do the rest.

But the engine designer, despite the achievements credited to him yesteryear, has a great deal of study ahead. For example, an 83 bhp engine of 1933 vintage was modified in 1941 to produce a peak output of 150 bhp. Further changes have raised its output to 170 bhp in the laboratory. This is



General Chairman of the meeting W. W. Churchill is shown in action as presiding officer. Left to right: D. D. Thomasson, Northwest Section chairman; SAE President L. Ray Buckendale; Toastmaster W. J. Miller; Mr. Churchill; Edward F. Lowe; P. J. Schrodt, chairman, SAE British Columbia Group, and N. J. Buren, vice-chairman Tacoma Group

FUTURE

Meeting

Welcoming the SAE National Transportation & Maintenance Meeting, Aug. 22 to 24, Councilman Mike Mitchell represented the Mayor of Seattle. SAE President L. Ray Buckendale is at the right. More than 300 attended the important one-day event

the result of a number of refinements, the engine being basically the earlier design. His audience was startled with the statement that weight decreased from 10.54 to 6.3 lb per hp, despite refinements incorporated.

Supercharging will be relied upon as design improves to get more power out of an engine to satisfy demands of fleet operators. A simple preliminary test showed a gain of 20% in bhp, along with an increase of 28% in torque by supercharging a conventional engine. Mr. Shoemaker also discussed new developments resulting from researches in water injection. He went further and gave his audience a glimpse at what the future may hold for operators in turbo powerplants, but warned them to wait for necessary metallurgical developments, as well as torque conversion devices, which he counted as essential factors.

Commenting on this look into the future of powerplants, Errol J. Gay emphasized the importance in considering the triumvirate of fuels, lubricants, and engines is the *sine qua non* in considering the more economical engine of tomorrow. Only with this in mind can the engine designer achieve the optimum results.

If the periodic trouble of valve deposits is here to stay, Mr. Gay suggested that fuel injection should eliminate this trouble. At the present state of the art, injectors are expensive, but in view of increased operating economy fuel injection may serve to reduce costs in the long run, he thought.

The Ethyl Corp. engineer saw no economy in inferior lubricating oils – at *any* price. Wages of mechanics are on the upswing, and engine overhaul is increasingly expensive, he pointed out. In his studies of the requirements of motor vehicle operators, he has been convinced that the higher output engine, to operate as economically as possible, is inevitable. It was difficult for him to see lower overall maintenance costs in the projected engine of the future.

Although the diesel engine has made an important contribution to operating economy under certain conditions, he feels that the more powerful gasoline powerplant of the future is on its way in development laboratories of the automotive industry.

This expose of the engine of the future, with refinements borrowed from aircraft engine experience, delighted another speaker, J. C. Sheasgreen, who is in the lumber business in the Northwest. Because of the rugged terrain and the huge and shifting loads, trucks cannot be too good. Up there, apparently, they break up the strongest frames, tear out oversized rear axles, and strip sturdy transmissions galore. Where the timber stands high, men talk in terms of 250 bhp engines, lots of size in tires, transmissions of herculean strength to replace tandem gear boxes. Axles that could take beatings beyond the imagination of drivers who merely pilot their courses on concrete highways are needed.

He glanced backward at the billion feet of logs handled by trucks during the past decade for only a moment, and then declared that almost any logging operator can make a success with trucks. If he is not truck logging now, Mr. Sheasgreen said, he will be. His company Logging & Railway Co. is truck logging, and back he went to the tall timbers to help get out a part of that next ten billion feet.

Urges Systemitization

One of the serious aspects facing successful logging operations continues to be a major engineering problem with all fleet management. Vehicle maintenance needs to be systematized, Wallace Linville told his audience in a careful summary of a survey he conducted to bring more facts into focus.

The owner of Acelin Co. concluded that a considerable portion of a fleet's mechanical overhauling work should be put on a production line basis. Professional engine rebuilders, he reported, have taken a page from the book of the engine manufacturers and have successfully installed special machine tool equipment on a considerable scale. He cited the use of a borer which rebores an engine block in only nine minutes.

"The rugged Jack-of-All-Trades must more and more look to heaven for his reward," he said, in predicting a strong trend toward production line overhaul of transmissions, rear axles, generators, starters, distributors, fuel pumps, and carburetors. Fleet operators with sufficient volume of work must

get their shops systematized, if they are to survive in today's march of progress.

Mr. Linville showed, on the basis of his analysis of more than 36,000,000 road failures reported in 1945 by AAA contract garages from coast to coast, that the largest percentage of mechanical troubles are caused by battery and ighition troubles. He then detailed several trouble-shooting check lists to aid the mechanic to find potential troubles in the least possible time.

He demonstrated his idea of efficient maintenance equipment with an engine tune-up bench, tool board, and other equipment so arranged to save time. He is an advocate of the movable work bench, where the mechanic has all the generally used tools nearby.

First step in vehicle maintenance, Mr. Linville remarked, is to analyze the job. Then the work should be carefully specified, so everyone concerned will know what his specific duties are.

Thirdly, the operation must be simplified. He detailed how revisions had been made in several operations to reduce wasted and duplicated effort.

Doing the job, the fourth step, must be systematized, and he outlined the list of tools required for various maintenance jobs. Inspection and records play an important part in the program, the author concluded.

During the discussion, Mr. Linville told his audience that burning out carbon was a "poor way out of trouble." He pointed out that often serious damage is done to the engine when carbon is burned. Although more expensive, a good cleaning of the engine pays in the long run, he said.

In his discussion of doing the job, Mr. Linville touched on the importance of efficient shop layout. P. J. Schrodt, B. C. Motor Transportation, Ltd., presented a careful study of this question using detailed examples from the garage facilities of his operation, the Pacific Stage Lines in Vancouver.

Work Flows Smoothly

Again adopting the production line technique of the manufacturers, this bus garage is designed to permit a smooth flow of equipment through the various stages of the shop and out. Ramps are used. The author is an advocate of well lighted and fully ventilated pits, of which there are five. Recesses in the pits have been cut to provide tool shelves.

No wild prophet, Oscar H. Banker proved to be a careful engineering thinker when he concluded that automatic transmissions were a "must" in design thinking for tomorrow's products. He confessed that 18 years ago he predicted that wide use of these devices was on the threshold of automotive vehicle production.

Lack of fundamental understanding of both the limitations and the requirements of such devices doomed many earlier efforts to failure.

Probably the first commercial application was on the 1904 Sturtevant, a two-speed centrifugally controlled automatic transmission. It was not until 1934 that the pioneer of modern automatics, the Mono-Drive, was put into a bus in Chicago and 18 months later moved to the Fifth Avenue Coach system in New York, Mr. Banker recounted.

Now after 10 years, 384 are still in use in those cities and in Los Angeles.

Another engineer, G. V. Edmondson, reported that his company, The American Blower Corp.. is working on the theory that fluid coupling performance will enhance transmissions. The two are interdependent. A unit used in Chicago is made of pressed parts welded together, eliminating the weight and flywheel action of a bolted ring. Cast iron construction has been generally discarded.

"Experience is the best teacher, and for experience there is no substitute," he said, in mapping the development of automatic torque converters. Close cooperation between the vehicle manufacturer, user, and the transmission engineer had proved to solve earlier difficulties that once appeared to have no answer.

The keynote of the meeting – more economical maintenance procedures and improved equipment – was again resoundingly struck by R. A. Watson and W. E. Thill, who reviewed an analysis of sleeve bearing materials undertaken by Federal-Mogul Corp.

It appears to them that the work which a given bearing is able to withstand without deterioration is impossible to compute through present knowledge of bearing linings. Maximum factors were established many years ago, and newer materials have found their respective places in this line-up.

In their exhaustive interpretation of why one bearing is recommended for use in one application and another for another, they set up these values totaling 100% for nine desirable characteristics:

Fatigue resistance 60%; Conformability and Embeddability, 10% each; Antiscoring, Corrosion Resistance, and Shaft Hardness, 5% each; Bond and Temperature-Strength Ratio, 2% each, and Thermal Conductivity 1%.

The authors plotted a series of eight lining alloys of curves against these nine desirable physical characteristics. The alloys were tin base babbitts, high lead babbitts, cadmium alloys, copper alloys, copper alloys which were overplated, aluminum alloys, silver, and silver overplated. Current practice is to overplate some of the alloys to increase the conformability of the bearing, as well as increasing resistance to corrosion and improving its anti-scoring characteristic.

Overplating silver brought that bearing material to the top of the list in respect to fatigue resistance, it was found in the aircraft engine industry.

But they warned vehicle operators that it was dangerous to assume that a bearing material, which operates satisfactorily under one set of circumstances, will prove best under others. Crankshaft journal conditions are different, and other engine characteristics may require entirely different materials.

It is still a universal mystery why an alloy of certain constituents called "A" behaves well wherein a lubricated shaft turns while loaded, and another containing other materials may be a total failure under exactly the same conditions.

Hence one bearing is recommended by the manufacturer for a given set of operating conditions, whereas an entirely different material – and probably different construction – appears the optimum for other applications.

Manufacturing procedures, which were counted upon by the speakers as being of extreme importance, were also outlined. The three general methods of making bearings are by casting, tubing, and strip. They indicated that the tremendous impetus given to bearing research for the aircraft industry the past few years has served to advance the techniques and provide the vehicle industry with bearings of longer life than envisioned a decade ago.

In the meantime, the audience of fleet operating engineers was told, bearing and engine manufacturers are working closely together improving bearings and seeking to increase the life of these units in an effort to reduce the overall costs of highway transportation.

Aluminum Alloys for BEARINGS

FROM A PAPER BY **H. Y. HUNSICKER** AND **L. W. KEMPF***

ALUMINUM-TIN alloy bearing life of from 200 to 500% longer than high quality copper-lead, cadmium base or "micro-babbitt" bearings has been attained in laboratory tests.

Adequate mechanical strength to support severe bearing loads without a detrimental reduction in the conformability and embeddability characteristics can be achieved in the aluminum-tin alloys by means of properly balanced additions of hardening elements. Aluminum-tin alloys with yield strengths (0.2% permanent deformation at room temperature) of 8000 to 10,000 psi have successfully met the requirements of the bearing function in applications which do not impose major stresses other than those developed by the bearing load.

Some of the data in tests of the Al-Sn-Si-Cu alloy, a tin base babbitt and a 70 Cu-30 Pb in the Timken Lubricant Tester are presented in Fig. 2. The tester is shown in Figs. 2 and 3. The coefficient of friction and volumetric wear of these materials after a test of 10 min duration at the highest speed which was available and with a refined straight mineral oil of 55 SSU viscosity at 100 F are plotted as a function of the applied load.

There is little difference in the wear of the various materials at the lower loads, but at a load of about 400 lb the babbitt wiped badly. The aluminum alloy operated successfully with low wear at the 617 lb load, and the unit bearing pressure at the end of the 10 min period amounted to 3800 psi.

The frictional coefficient of the babbitt was considerably higher than that developed by either the aluminum alloy or copper-lead. At this speed the copper-lead was not operated at loads in excess of about 200 lb because of the high temperature produced.

There is good agreement in the results of the tests which have been made in two different types of machines under widely varying conditions leading to the conclusion that the Al-Sn-Si-Cu alloy possesses an outstanding ability to withstand conditions of thin-film lubrication or metallic contact developed by very high bearing pressures.

The Al-Sn-Si-Cu alloy has been tested in several engines in which the Al-Sn-Ni-Cu alloy had operated successfully, and the results were not significantly different with the two materials. In one engine in which it had not been possible to operate the original alloy successfully because of scuffing or galling, the silicon-containing alloy performed satisfactorily.

Furthermore, the Al-Sn-Si-Cu alloy is equal in fatigue resistance to the Al-Sn-Ni-Cu alloy and in the same measure superior to the usual bearing materials. The high resistance to corrosion of the aluminum-tin alloys is not impaired by the addition of silicon and the Al-Sn-Cu-Si alloy is not attacked by acid-containing oils at high temperatures.

The rate of journal wear experienced in applications of the aluminum alloys has been similar to that resulting from the

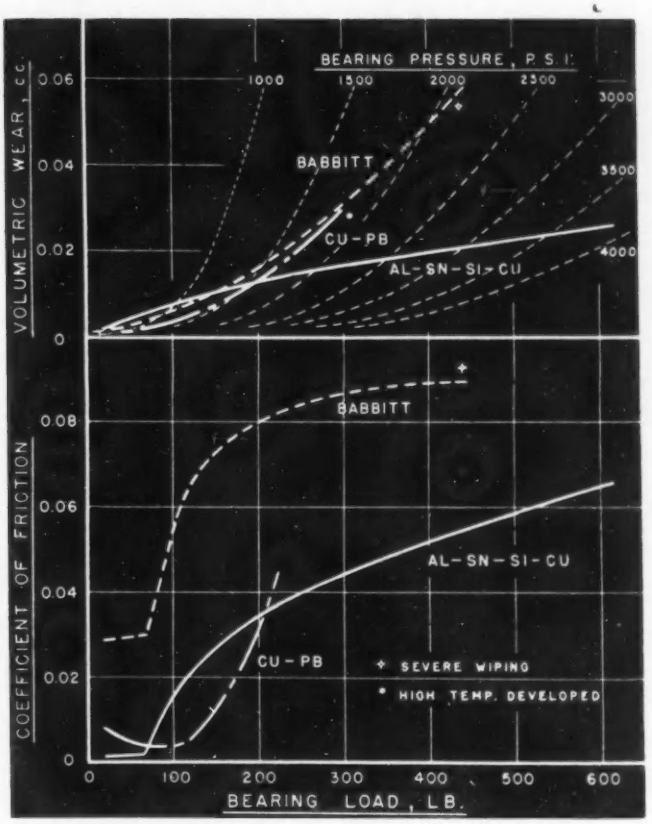


Fig. 1 – Comparative performance of bearing materials in the Timken Lubricant Tester. Speed, 575 fpm; straight mineral oil, 55/SSU/100 F; test duration was 10 min

* Original paper "Aluminum Alloys for Bearings," by H. Y. Hunsicker and L. W. Kempf, was presented at the SAE Summer Meeting, June 6 1946.

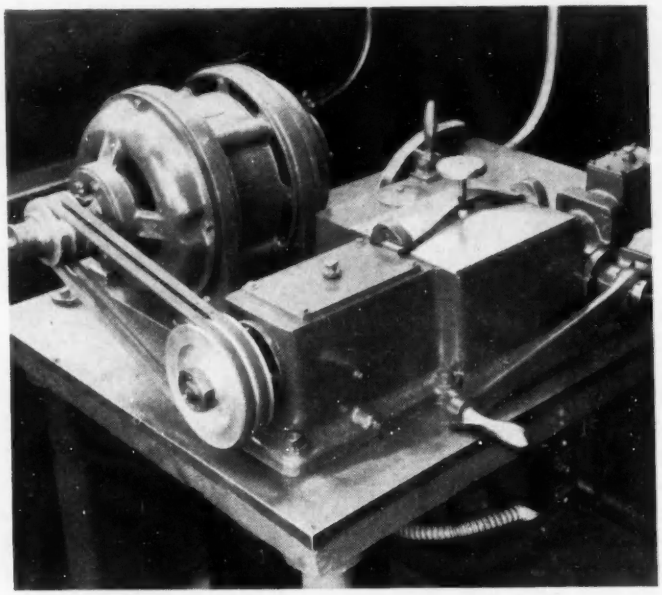


Fig. 2 – Scuffing test machine, modified from the General Motors Research Laboratories machine

operation of copper-lead bearings and somewhat greater than that usually encountered in comparable installations of babbitt bearings.

Each bearing installation is a different problem beset with mechanical and lubrication factors which influence the success or failure of the bearing. For this reason certain design changes are frequently required to adapt the installation for aluminum bearings. Such changes may involve the method of locking the inserts in place, the wall thickness to diameter ratio of the inserts, the initial interference fit, the diametrical clearance or oil grooving.

However, automotive connecting rod and crankshaft "precision" bearings are normally installed with an interference fit in the rod and crankcase bores to position them rigidly in the bearing housing and provide the minimum resistance to the flow of frictional heat from the bearing to the housing. In applications involving anti-friction metal lined – steel backed bearings installed in ferrous alloy housings – the similarity of the thermal coefficient of expansion of the mating components permits a stable mechanical fit over a considerable range of operating temperature. This is likewise true of solid aluminum alloy bearings assembled in aluminum alloy connecting rods or crankcases.

On the other hand, installation of a solid aluminum alloy bearing in a ferrous alloy housing introduces a new mechanical problem, since the thermal coefficient of expansion of the aluminum alloy considerably exceeds that of the ferrous material. This thermal expansion differential raises the temperature of the bearing and will create thermal compressive strains in the tangential direction in the bearing which are additive to the strains developed by the initial interference of the assembly.

Stability of the mechanical fit of homogeneous aluminum alloy bearings in ferrous housings is governed, among other things, by:

Operating temperature range,

Difference in thermal expansion of the two metals,

Initial interference or prestress,

Ratio of section moduli of the bearing and supporting member, and

Mechanical characteristics of the aluminum bearing alloy.

The interrelations of all these factors, and others, have not yet been completely evaluated.

Significant properties involved in aluminum alloy bearing material are the magnitude of the coefficient of thermal expansion, and the resistance to deformation induced by the initial interference and the thermal compressive strains prevalent during the high temperature portions of the thermal history of the assembly.

Obviously, for perfect mechanical stability, there can be no relaxation of the bearing. However, in most practical cases a certain degree of permanent deformation will be encountered. The optimum material, from this standpoint, will be that which has the lowest rate of relaxation.

Particularly complex and difficult mechanical, metallurgical and chemical requirements must be fulfilled by a successful high duty bearing material. Requisites include:

1. Resistance to Scoring and Galling. The ability of the material to operate through periods of high local stress is a function of the mechanical properties, which may determine the probability of the occurrence of lubricant film rupture while the chemical nature of the material comes into play in the event of lubricant breakdown.

2. Resistance to Pressure. The material must be of sufficiently high compressive yield strength to prevent measurable permanent deformation under the imposed bearing load, but should be plastic enough to allow slight local deformation to accommodate shaft misalignments or deflections, local imperfections in the surface contours, and foreign particles. A low modulus of elasticity is also believed to be advantageous.

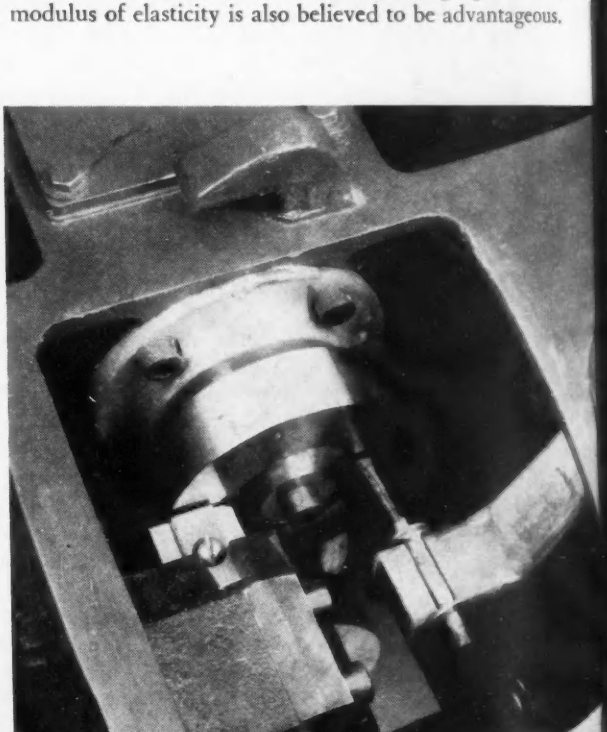


Fig. 3 – Closeup of scuffing test machine with top removed

3. Resistance to Fatigue. The bearing life under ordinary circumstances is determined by its fatigue resistance.

4. Resistance to Corrosion. The bearing material should not deteriorate chemically in its environment of lubricating oil and the decomposition products of the oil at operating temperatures.

Attributes of the bearing material which are of assistance in meeting these requirements are:

a. Good thermal conductivity to aid in dissipation of frictional heat and minimize the formation of local hot spots.

b. A tendency to absorb and retain a continuous oil film.

c. Freedom from abrasive effect on the journal as well as the ability to embed foreign abrasive particles.

Early tests of a variety of cast and wrought commercial aluminum structural alloys led to the conclusion that these could operate satisfactorily as connecting rod or crankshaft bearings only under the most favorable conditions.

At moderate bearing pressures and temperatures, with optimum alignments and rigidity of journal and bearing supporting members, and with ample supply of clean lubricant, these alloys could be used. But anti-scoring qualities were generally inadequate to allow continued operation under conditions of boundary lubrication or partial metallic contact. Differences in scuffing tendencies which could be attributed to chemical composition and microstructure were detected among the commercial aluminum alloys.

Alloys characterized by heterogeneous structure with a considerable proportion of hard particles, such as those used for pistons, operated at definitely higher loads with lower frictional coefficients and less wear than alloys having an equivalent matrix hardness – but not containing relatively small proportions of insoluble hard phases. Observations and conclusions in this country generally paralleled those reached in both German and British investigations on this phase of research.

Because, therefore, there was little prospect that the ordinary aluminum alloys would have a wide applicability as high duty engine bearings, efforts were concentrated upon developing new aluminum-base alloys possessing more suitable characteristics.

First problem was to determine means of improving scuffing resistance. The most promising approach was found in adding metallic elements which would form a separate, insoluble, and soft constituent in the aluminum. Stable elements, available in commercial quantities which will fulfill this requirement are tin, lead, cadmium, bismuth, and indium.

Aluminum-lead showed a low solubility of lead in aluminum in the liquid state. Fairly uniform castings or ingots containing up to 1.5% lead can be made by use of normal melting and casting temperatures. The resulting microstructure contains small spherical globules of lead in the aluminum matrix, and is considered favorable for high fatigue resistance.

Anti-scuffing was improved by increasing lead concentrations, but the lead tended to flake off in the presence of certain lubricants at elevated temperatures.

Aluminum-bismuth proved to be similar, in general, to the aluminum-lead compositions, both in respect to metallurgical and scuffing characteristics. Mixtures of up to 20% bismuth were tested.

Aluminum-cadmium compositions also showed that the latter element is only partly miscible in aluminum in the liquid state. The liquid solubility limit was found to be about 5% at 1209 F, and it increases somewhat with higher temperatures. Vaporization of cadmium from the composition was observed above 1412 F, the boiling point of cadmium. In excess of about 2% cadmium, some difficulty was experienced in preparing the melts, although castings of about 8% have been prepared in the laboratory.

Aluminum-tin alloys were found to be the most desirable bearing compositions from the standpoint of antifriction characteristics and resistance to corrosion in lubricants. No advantage was found in the addition of combinations of tin and lead. It is believed that the addition of very low melting eutectics may lead to troublesome effects of liquidation under severe operating conditions.

Presence of a third relatively hard constituent in the aluminum-tin alloys increases the load required to cause scuffing, reduces the coefficient of friction, and enhances wear resistance. It was found, in general, that the load-carrying capacity increased with the hardness of the third constituent.

Silicon additions increased the load-carrying capacity and wear resistance of aluminum-tin alloys under boundary film lubrication conditions. The silicon addition also functions as a structural refiner aiding to achieve favorable dispersion of the low melting constituent of the alloys.

High resistance of aluminum-tin alloys to corrosive attack by organic acids formed on the breakdown of lubricating oils during use (Fig. 1), is a definite advantage and leads to the possibility of using compounded oils in engines where previously corrosion of bearings made it impractical to take advantage of the superior properties of such oils.

Compounding to increase the lubricating qualities of the oils, or to prevent accumulation of engine deposits, ring sticking, and other troubles, is made possible by the improvement in the chemical stability of the bearings.

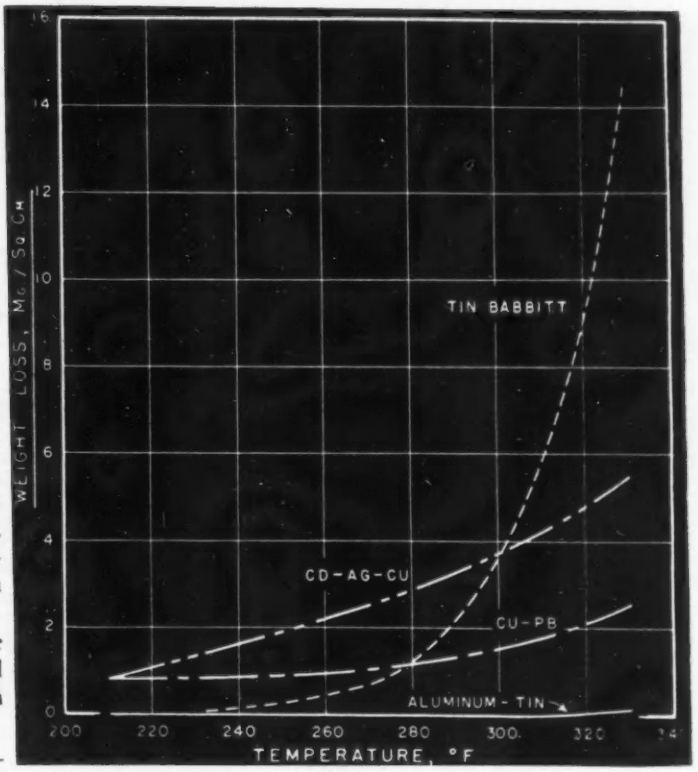


Fig. 4 – High resistance of aluminum-tin alloys to corrosion is shown by comparison with three other materials. Al-Sn shows loss appearing at about 320 F

Coming Motor Fuel

FROM A PAPER BY **EARL BARTHOLOMEW***

MOTOR fuels becoming available, as well as those in prospect, offer quite attractive increases in both fuel economy and power output per cubic inch of engine displacement. Higher compression or increased manifold pressure may be employed with improved antiknock fuels to provide either a substantial increase in vehicle performance or fuel economy, or a smaller simultaneous increase in both.

Realization of improved gasoline potentialities poses major problems for the engine designer. His objective of maximum output and highest efficiency in the smallest package, within limits of acceptable cost, must integrate these three inseparable design factors:

1. Properties of fuels and lubricants which will be used;
2. Dimensions of the parts and the overall structure;
3. Composition of the components.

* Paper "Potentialities of the New Fuels in the Design of Passenger Car Engines," by Earl Bartholomew, Ethyl Corp., was presented at SAE Summer Meeting, June 3, 1946.

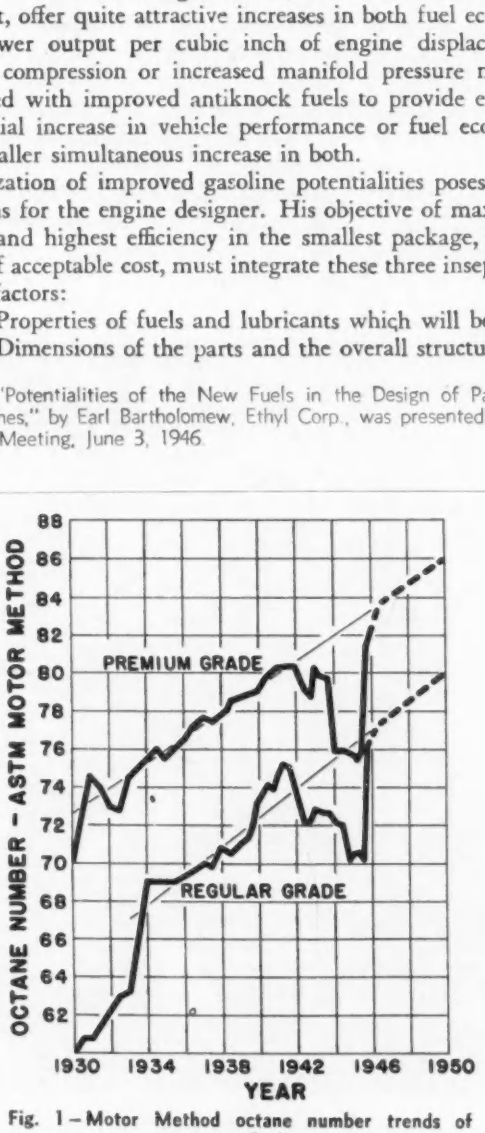


Fig. 1 – Motor Method octane number trends of motor fuels

Numerous forecasts have been made as to the trend of antiknock quality in the future. The projection in Fig. 1 is based on extrapolation of the prewar trend without upward adjustment for the unusual refinery construction during the war. On this assumption, premium and regular grades would have Motor Method octane numbers of 86 and 80, respectively, in 1950.

Octane numbers determined by any single method do not reflect the relative performance of fuels in all types of engine under all conditions of operation. It is generally recognized that ratings by the ASTM Motor Method are not satisfactory indexes of the relative antiknock performance of gasolines in passenger cars, particularly under conditions of low speed knocking. Although the Research Method ratings do not correlate too well with such road performance, they are more satisfactory than Motor Method ratings in this respect.

Fig. 2 shows the octane number trends of motor gasolines, as determined by the Research Method, for the period beginning in 1943. The increase in Research Method octane numbers in the period between V-J Day and March, 1946, was greater than the improvement in Motor Method octane numbers, reflecting the effect of refining equipment shifted from the wartime aviation gasoline program to the production of motor fuels.

In general, catalytically cracked stocks have Research Method octane numbers much higher than Motor Method ratings. The average "sensitivity" of premium grade fuels – Research Method rating minus Motor Method rating – is increasing steadily. It has been assumed in Fig. 2 that the present spread will be maintained until 1950, and that Research Method octane numbers will increase at the same rate as Motor Method ratings. Average Research Method octane number of premium and regular gasolines would be 93.5 and 86.0, respectively, in 1950.

Conservatism of these estimates is indicated by the quality of the best motor gasolines marketed during the first part of the current year, as shown in Table I.

These Motor Method octane numbers are substantially the same as those predicted as averages for 1950. Research Method octane numbers are well above the estimated averages for 1950. Some fuels now more than meet the antiknock quality estimated for 1950, while others are substantially below. Quality of fuels produced by any one refinery at present depends

Promise Improved Economy & Performance

Fuels with octane numbers of 85 to 90 will soon be available, predicts Mr. Bartholomew. They offer advantages of greater fuel economy and better-on-the-road performance.

If high octane fuels are to be exploited for these potential benefits, engine designers must resort to higher compression ratios and supercharging for increased intake manifold pressure. Why and how these changes manifest inviting results are also shown in this article.

Mr. Bartholomew advises that present day engines are not equipped to operate under these more stringent conditions. He carefully points out those engine features which must undergo radical redesign to accommodate these new operating conditions.

largely on the degree to which it participated in production of wartime aviation fuels.

Much attention is being given to the development of relatively low cost catalytic cracking units of small capacity. Superfractionation of straight-run gasoline, a shift toward the vapor phase type of thermal cracking, and removal of sulphur compounds rather than their conversion all offer a means of effecting substantial improvements in octane ratings. It appears likely, therefore, that refiners will be able to devise means to continue the trend toward higher antiknock value in motor fuels.

Fuel Quality and Engine Design

Average fuel antiknock quality since V-J Day has reached the highest point in history. Predictions are being made that it will rise to considerably higher levels during the next few years. This all gives rise to the question generally being asked, "What are the possible improvements in engine performance resulting therefrom?"

Many opinions have been advanced within the past year on this relationship. They vary from the belief that the potentialities are insignificant to the prediction that engines will be reduced to a fraction of their present size and will deliver 50 mpg. Lack of agreement seems to justify a study of the problem in the light of available information.

A combination of experiment and basic thermodynamic principles has proved to be quite useful. It provides a broad background against which useful predictions may be made of performance to be expected from engines of assumed design when installed in vehicles having hypothetical characteristics.

Potentialities of improved fuel antiknock value may be realized in Otto cycle engines by:

1. Increased compression ratio,
2. Higher volumetric efficiency,
3. A combination of the two.

Efficient application of the two basic principles to the passenger car engine involves widely different problems and designs.

It is generally known that an increase in either compression ratio or volumetric efficiency of an engine adds to the knocking tendency. Present rapid increases in antiknock quality of motor fuels suggest the possibility that engine designers may wish to change both compression ratio and volumetric efficiency. It is desirable that some indication be obtained of the effect on knocking tendency resulting from simultaneous variations in the two factors.

Such a study has been carried out on a single cylinder engine equipped with a variable compression, 24.35 cu in. valve-in-head cylinder, and capable of operation over a wide range of intake manifold pressures at closely controlled speeds up to 3000 rpm.

A number of gasolines were tested, each having a Motor Method octane number of 80 and containing more than 50% of one of the common classes of hydrocarbons. The tests were run at knock-limited intake pressure over a wide range of compression ratios at speeds from 600 to 2500 rpm.

Fig. 3 shows a chart for the highly paraffinic fuel with a similar chart for the same fuel containing 3 ml tetraethyl lead per gal. Paraffin hydrocarbons occur in high proportion in straight-run and alkalyte fuels.

As would be expected, the permissible manifold pressure at any particular engine speed decreases as the compression ratio is increased. As engine speed is increased, higher manifold pressure and compression ratio may be used. When tetraethyl lead is added to the fuel, the general relationships between the three variables remain essentially unchanged, but the levels of permissible compression ratio and manifold pressure are materially raised.

For example, at 600 rpm and 6 to 1 compression ratio, the knock-limited manifold pressure is increased from 34 to 44 hg abs.

A further complication is introduced in the multicylinder passenger car at low engine speed by unequal distribution of unvaporized heavy ends of fuels to the different cylinders. Therefore, the fuels which give best low speed performance are those having in their more volatile fractions the maximum concentration of high antiknock hydrocarbons possessing rela-

Table 1 – Maximum Quality of Commercial Motor Gasoline (February, 1946)

Grade	Octane Numbers	
	Motor	Research
Premium	85.3	95.4
Regular	80.6	89.6

tively good low speed quality. In a comparison of two fuels having the same Motor Method knock rating, one with a large proportion of high antiknock aromatics and olefins in the volatile fractions with relatively low antiknock paraffins in the heavy ends gives better low speed performance than one having low antiknock paraffins in the volatile fractions with a considerable concentration of olefins in the heavy ends.

It is apparent that the designer of engines for new fuels must reckon with more than Motor and Research Method octane numbers. He must understand the potentialities of the different types of fuels with respect to compression, volumetric efficiency, and speed. He must also have a knowledge of the volume in which the different types of fuels are likely to be produced.

The fuel refiner should likewise understand these engine-fuel relationships to adjust fuel compositions to the trends of engine design dictated by transportation requirements. The problem calls for closest cooperation between technologists of the oil and automotive industries.

Effects of knock-limited compression ratio and intake manifold pressure on car performance and fuel economy are of interest to the engine designer. End possibilities of the two methods of utilizing fuel antiknock value can be visualized only through an understanding of their basic relation to mean effective pressure and fuel consumption.

These relationships are illustrated in Fig. 4 and 5, respectively, as developed at 2500 rpm on the small valve-in-head engine. Inasmuch as mechanical efficiency of different types of engines covers a considerable range, the presentation is made on the indicated basis.

Fig. 4 indicates that a wide range of mean effective pressure at maximum power spark advance may be developed at any fuel octane number, depending on the combination of compression ratio and manifold pressure employed. Output at any particular compression ratio is substantially a linear function of manifold pressure. At any manifold pressure, the incremental power increase becomes smaller as the compression ratio is raised, in accordance with the characteristics of ideal air cycles.

Fig. 5 shows that a wide range of specific fuel consumption is possible under the engine conditions of Fig. 4. It also shows that the combination of compression ratio and manifold pressure which yields the highest fuel economy at any fuel octane number is that which produces the lowest mean effective pressure. At any given compression ratio, indicated specific fuel consumption is substantially independent of manifold pressure; but at any particular manifold pressure, specific fuel consumption becomes better as the compression ratio is increased.

Basic potentialities of the two methods of antiknock utilization become apparent. On the road the relative gasoline mileage at different compression ratios and manifold pressures may vary from the pattern of Fig. 5 because of engine friction and the characteristics of other components of the chassis.

It has been shown that new fuels offer considerable latitude in the choice of manifold pressure and compression ratio. Building of experimental engines to be installed in cars for tests of all possible combinations is prohibitively expensive and time consuming. Some simple means for estimation of the

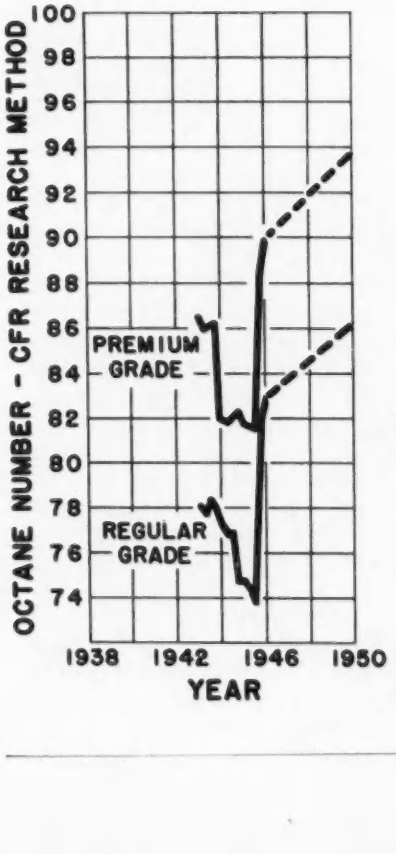
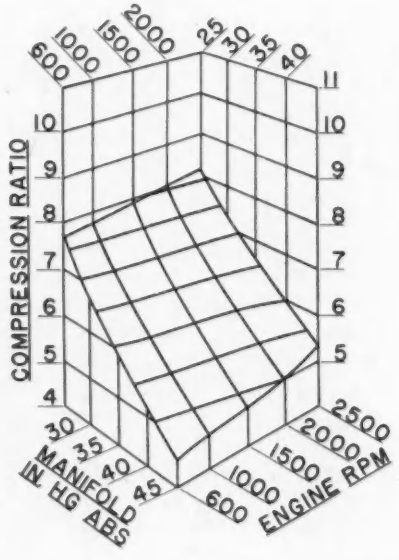


Fig. 2 (left) – Research Method octane number trends of motor fuels



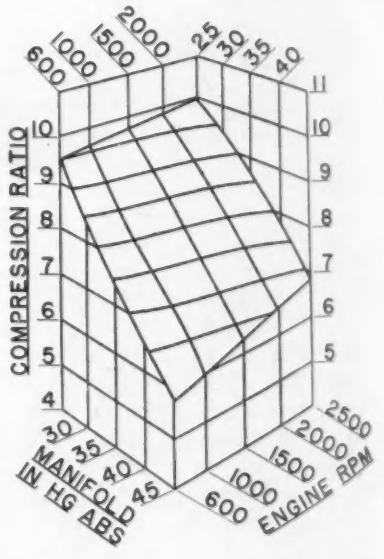


Fig. 3 (above) – Relationship of maximum compression pressure, manifold pressure, and speed effect that may be employed with a highly paraffinic fuel. Chart on right shows effect of adding 3 ml of tetraethyl lead per gal to this fuel

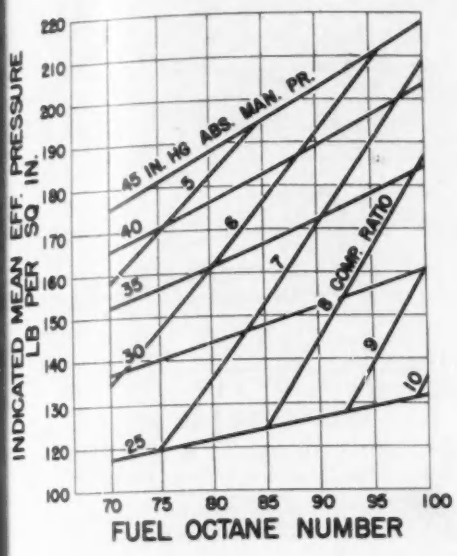


Fig. 4 – Effect of compression ratio and manifold pressure on octane requirement and power

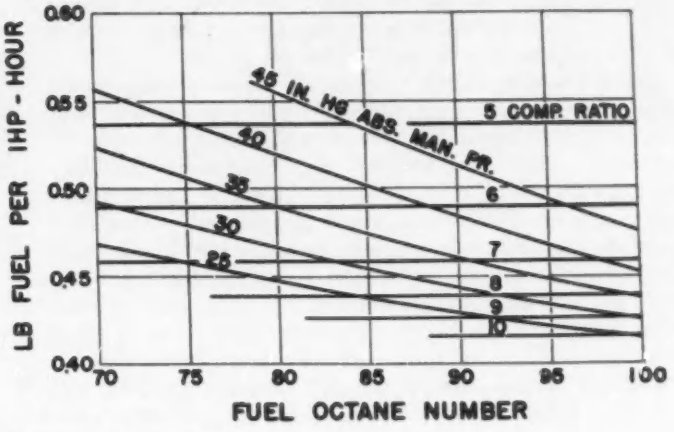


Fig. 5 – Effect of compression ratio and manifold pressure on octane requirement and fuel consumption

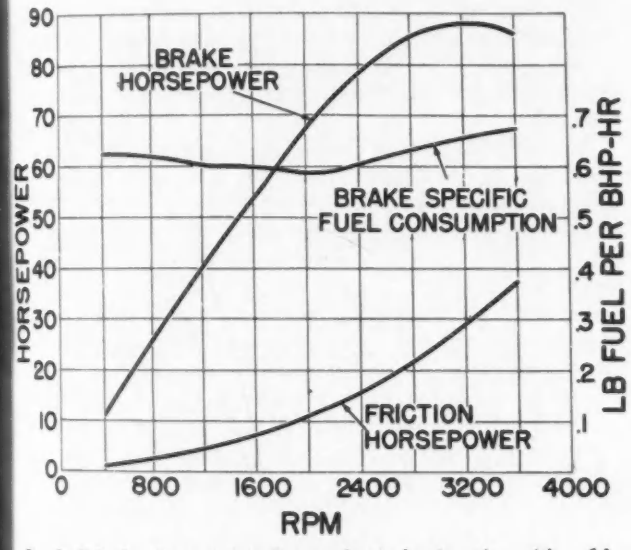


Fig. 6 – Full throttle test data for a valve-in-head engine with a 6.1 compression ratio

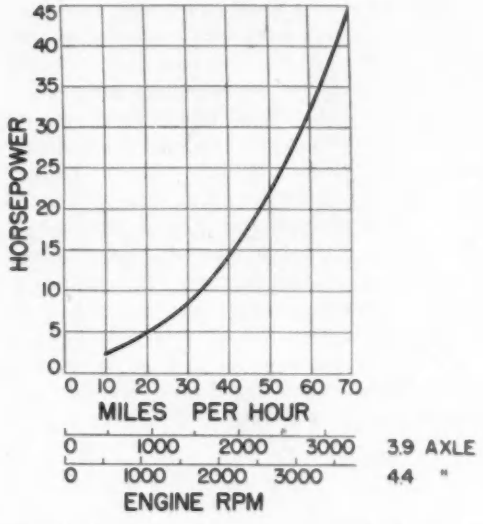


Fig. 7 – Level road power requirement of a car equipped with the engine of Fig. 6

overall percentage improvement in level road car performance and economy obtainable from any given change in compression ratio or manifold pressure is desirable.

Calculations based on fundamental relationships and information on the car and engine requirements provide the basis for forecasting economy and performance without expensive tests.

Higher Compression Ratios

There is at present considerable speculation on the improvement possible with compression ratios of the order of 8.5, requiring road octane number fuels of 90 to 95. Tests have been made on a valve-in-head engine at this compression ratio, both on an engine dynamometer and in a car equipped with both 4.4 and 3.9 rear axle gears.

Similar tests have been made at a 6.1 compression ratio requiring road octane fuel numbers of 73 to 78, on the same basis that the 90 to 95 octane fuels were selected for the 8.5 compression ratio. These same compression ratios were chosen for the computation so that the calculated improvement might be compared with that observed in the car tests.

Fig. 6 presents the basic test data for the completely equipped engine at 6.1 compression ratio. Fig. 7 shows the level road power requirement of the car.

Power and fuel economy data of Fig. 7 are calculated on the indicated basis in Fig. 8. Indicated horsepower at the 8.5 compression ratio is shown as an 11.7% increase over the indicated horsepower at 6.1 compression ratio. This is so because the thermal efficiency of the ideal air cycle at 8.5 compression ratio is 11.7% greater.

Percentage improvement in mpg over the speed range for the 8.5 compression ratio, with both axles, relative to the economy of the 6.1 ratio with 4.4 axle is shown in Fig. 9. The average gain between 20 and 67.5 mph is approximately 10%

at the same axle ratio. A gain of 19% is noted with the 3.9 rear axle which, with the 8.5 compression ratio, gives substantially the same low speed performance as the combination of the 6.1 compression ratio and 4.4 rear axle.

Without change in axle ratio, the higher compression would be expected to give an improvement in acceleration ability considerably greater than the percentage gain in fuel economy.

Carefully controlled fuel economy and acceleration tests were carried out in a car equipped with the engine on which the data in Fig. 6 were obtained. Fig. 10 shows the measured percentage improvement in fuel economy for both axle ratios due to the use of the 8.5 compression ratio. Although the gains at each speed vary somewhat from the calculated improvements shown in Fig. 9, the average gains over the speed range are of the same order – 12% with the same axle and 21% with the axle change.

As was pointed out, power output at any particular compression ratio is substantially proportional to charge density in the manifold; specific fuel consumption is practically constant. Apparently supercharging offers a means of utilizing improved fuel antiknock value for production of a large amount of power from a relatively small displacement, but without improvement in fuel economy.

Both engine friction and pumping losses are important factors in determining fuel economy of an installed supercharged engine.

It is interesting to note from test observations that the average brake specific fuel consumption for the supercharged engine, at a given speed and mixture ratio, is substantially the same as that of the naturally aspirated engine at full throttle. This relationship has been found to hold for different types of automobile engines over a substantial range of boost.

A small supercharged engine, having substantially constant brake fuel consumption over the manifold pressure range above atmospheric, offers interesting possibilities from the standpoint of fuel economy.

On the basis of experimental results, it is believed that the small boosted engine could be operated at an absolute manifold pressure of at least 40 and possibly 45 hg, at 6.1 compression ratio, and maximum spark advance on fuels having a road octane number of 95. Calculations indicate the displacement could be reduced to about 74% for the 40 in. manifold pressure and 66% for the 45 in. pressure of a naturally aspirated engine with the same compression ratio and 4.4 rear axle.

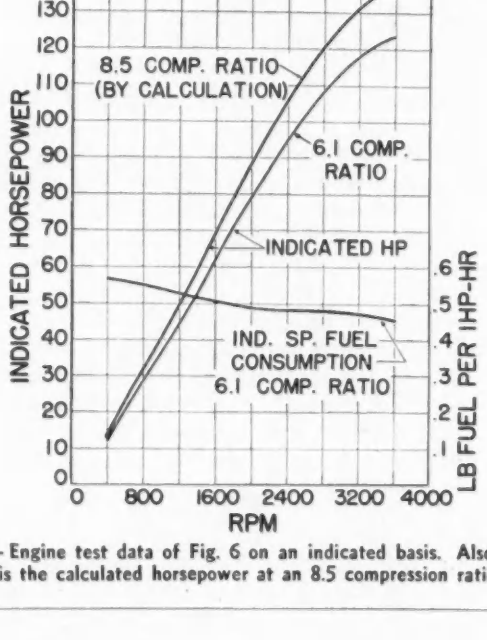


Fig. 8 – Engine test data of Fig. 6 on an indicated basis. Also shown is the calculated horsepower at an 8.5 compression ratio

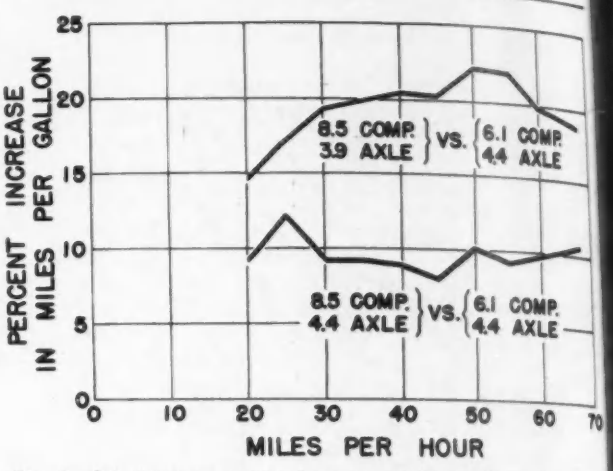


Fig. 9 – Calculated percentage improvement in gasoline mileage for the engine of Fig. 6 due to changes in compression and axle ratios

Further calculated, in Fig. 11, is an increase of 16% in mpg for the 40 hg abs engine and a 23% increase in mpg for the 45 in. manifold pressure engine. It is interesting to note that, at constant level road speeds up to 70 mph, both of the smaller engines would operate at manifold pressures below atmospheric.

Improved antiknock quality fuels have been shown to lend themselves to better vehicle performance or greater fuel economy using either higher compression or increased manifold pressures. But as is true in every phase of engineering progress, you cannot rob Peter without paying Paul. Virtues of higher compression and increased manifold pressure carry with them problems for the engine designer – the engine must be engineered to accommodate these more stringent demands.

High Compression Engine Design

Attractive advantages of high compression engines requiring 90 to 95 octane number fuels on the road are accompanied by a number of formidable design problems. At a compression ratio of 8.5, explosion pressures are of the order of 1000 lb per sq in. compared to about 600 lb per sq in. at a compression ratio of 6.

Present engine structures are not equal to such pressures, either from the standpoint of torsional or overall rigidity, not to mention roughness. A test on a conventional passenger car engine, with a normal compression ratio of 6.1 showed a maximum torsional crankshaft vibration of 3 deg – double amplitude – at a compression ratio of 11.15. Piston deformation was sufficient, at the same compression ratio, to result in a large increase in friction which was substantially eliminated by pistons redesigned for greater rigidity.

High explosion pressures associated with high compression ratios increase maximum instantaneous bearing loads at low engine speeds and thus contribute to roughness in engines of low structural rigidity.

As compression ratios are increased beyond present values, combustion chamber clearance volumes become quite small.

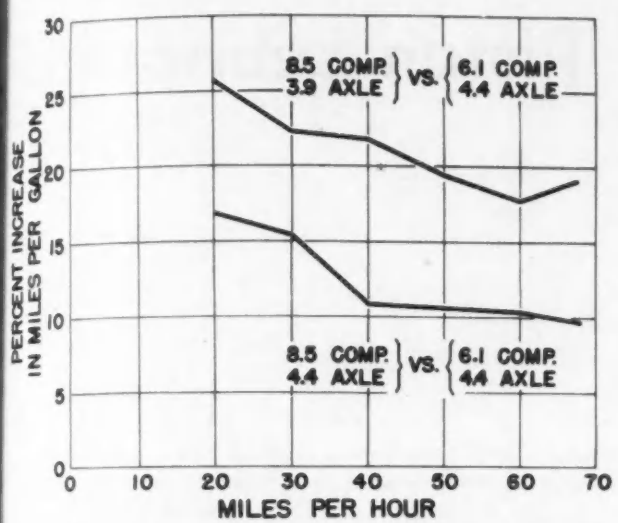


Fig. 10 – Measured percentage improvement in gasoline mileage due to change of compression and axle ratios shown in Fig. 9

Such small volumes require care in combustion chamber design to prevent loss of volumetric efficiency.

As the charge is compressed to higher pressures, the temperatures approach more nearly the self-ignition temperature of the fuel. Any hot spot may initiate combustion before regular ignition or ahead of the flame front while normal combustion is in progress. These abnormalities may cause apparent harshness of combustion without audible knock during acceleration; bursts of sharp knocking called "wild ping" or actual piston burning may occur.

The autoignition problem requires a thorough study including an investigation of the effects of carbon, combustion chamber shape, spark plug location, and effect of fuel composition.

Secondary ignition voltage which must be applied to the spark plug increases as the pressure in the cylinder becomes greater. For example, at 30 hg abs manifold pressure the voltage required at 9 to 1 compression ratio is about 20% greater than at 7 to 1. This effect creates two problems in the design of the ignition system:

1. Necessity for considerably increased secondary voltage which, in turn, increases the flow of energy between the breaker points and spark-plug electrodes.

2. Increase in tendency toward both external and internal flash-over.

Limitations of present low-frequency ignition systems suggest research on high-frequency systems having instantaneous starting characteristics.

Supercharging Design Problems

The discussion on the high degree of rigidity required in high compression ratio engines applies with almost equal force to engines of lower compression ratios supercharged to the extent made possible by 90 to 95 octane number fuels.

Engine-driven superchargers will be required to provide substantial boost over the entire speed range of the car. Noise level and cost must be low and reliability must be of a high order. Blowers meeting all requirements of passenger car service are not yet available; the need presents a real challenge.

The blower may be located either ahead of the carburetor or between the carburetor and the manifold. Each arrangement has its advantages and disadvantages. Blower installation should not add to the fuel distribution problem nor interfere with fuel flow required during acceleration.

In the case of an engine operated at an intake manifold pressure appreciably above atmospheric, the mixture temperature may be sufficiently high to depreciate the antiknock value of olefinic and aromatic fuels. With a blown carburetor, the high temperature of the air from the blower may cause vapor lock.

Supercharging increases the energy liberation per unit volume of engine displacement and consequently increases the temperature of all engine parts exposed to the burning mixture or the exhaust products. Spark plugs are subjected to a much wider range of temperatures. Insulator materials must have high fusion temperature, inertness to combustion products, and maximum possible thermal conductivity.

In contrast to increase in compression ratio, higher manifold pressure raises the temperature of exhaust gases. For example, an exhaust gas temperature of 1400 F was observed on a naturally aspirated engine at full throttle and 3400 rpm. When the intake manifold pressure was increased by 11.6 hg, exhaust gas temperature rose to 1525 F. Although not large on a percentage basis, a temperature increase of this magnitude may be quite important from the standpoint of behavior of steels used for exhaust valves.

If supercharging is to be used in the automobile engine, further studies should be made of the performance of valve steels at high temperatures. Efforts should be continued to develop an inexpensive type of internally-cooled valve. There appear to be possibilities in the design of exhaust valves and ports for lower valve temperatures. Exhaust valve diameters in particular appear to warrant investigation.

It has been reported that an increase in exhaust valve diameter in naturally aspirated engines reduces exhaust valve life and power output. No data are yet available indicating the advantages of a smaller diameter.

Potential improvement in fuel economy is particularly attractive from the standpoint of extending our petroleum reserves. It is also timely in view of the distinct possibility that the price of gasoline will rise because of added taxes and the greater cost of finding and producing oil. The potential saving would permit the operation of 5,000,000 additional automobiles in the United States without increasing the present rate of consumption.

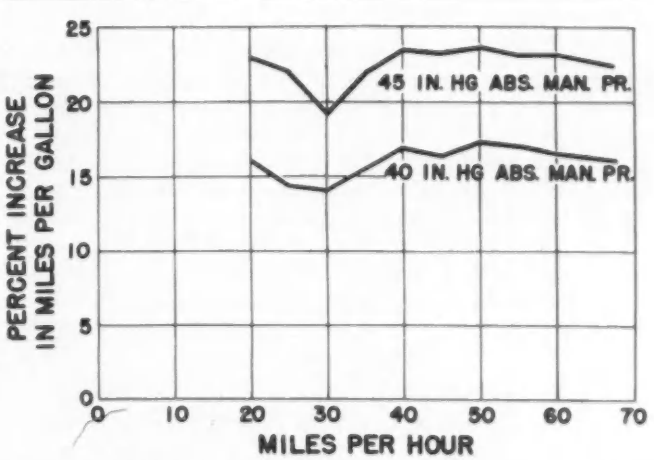


Fig. 11 – Calculated improvement in level road fuel economy of a small supercharged engine over the engine of Fig. 6

A PAPER BY

S. J. BEAUBIEN*

A. G. CATTANEO*

Piston Lubrication

FACTORS involved in piston lubrication have been observed and studied on a motored small bore engine equipped with a glass cylinder. The resultant picture of oil and piston ring movement reflects the primary effects of inertia and shearing forces. From both the observations made and a knowledge of combustion factors, an important conclusion can be drawn, namely: the major portion of oil consumption takes place on the exhaust stroke.

Mechanism of upper cylinder and piston ring belt lubrication is very complex. To further aggravate the problem, the region in which it functions is so inaccessible during engine operation that it is difficult to design tools and techniques with which to study it. Most of the knowledge on this subject has, in the past, been derived from indirect approaches based on measurement of heat flow, friction, blowby, or wear. Because of the complexity of the phenomena involved, the general validity of such measurements and their interpretation is subject to considerable doubt.

Direct knowledge of the details of oil flow and other mechanisms is still lacking. Yet without this knowledge, it is unlikely that designers of pistons, piston rings, and cylinders, or the manufacturers of lubricating oil, can achieve the best solution to such problems as ring sticking, scuffing, control of oil consumption, and wear which occur in this region.

To gain some insight into the movement of oil in the ring belt during engine operation, and into the action and movement of the piston rings by which the oil movement is largely determined, a visual study was made of the piston ring and oil relationship.

For this purpose, an engine was built with a glass cylinder to permit visual observation of oil, piston, and rings by stroboscopic and photographic means. The work was carried out by motoring this engine without combustion. This was done for several reasons. The main reason was the much simpler instrumentation necessary as the need for cooling the cylinder and the possibility of introducing a measuring device through the combustion chamber was avoided. Therefore, only the effects of mechanical forces and not the effects of heat and pressure of combustion have been studied.

Engine Design

The engine used (Fig. 1) had a 2⅜ in. bore, 3¼ in. stroke, and maximum speed of 2000 rpm. The pyrex glass cylinder is nominally ¼ in. thick and precision bored to a tolerance of ±0.002 in. Piston clearances were made relatively large to exaggerate the oil flow patterns and facilitate observations. The skirt clearance was 0.015 in., ring side clearance 0.004 in., and ring gaps approximately 0.090 in.

The connecting rod was 8.856 in. long, longer than usual for a 3¼ in. stroke to minimize side thrust. The compression ratio was 2½. An SAE 30 lubricant at room temperature was used for the conventional splash lubrication. Intake air was passed through an ice tower during motored operation to keep engine temperatures from rising appreciably above room temperature.

Gears in the lower left corner of Fig. 1 are part of a phase-changing mechanism by which a stroboscopic light is timed to flash at any desired point of the piston's stroke. Continuous visual observation of the piston is possible in this way while the engine is operating at full speed. For photographic purposes, the stroboscopic light with its timing mechanism was used to trip a single flash Kodatron lamp.

As an initial step, the positioning of the top ring in its groove was determined by an electrical circuit which includes the rod emerging from the center of the piston and extending through a gland in the cylinder head. Fig. 2 shows the details of this circuit.

When the ring is on its lower seat, the stroboscope tripping circuit is completed through an outside sliding contact to the rod at the center of the piston, through the connecting wire to the ring, and so to the piston and engine frame. When the ring is on its upper seat, it touches only the glass cylinder wall and the top land made of electrically nonconducting material – shown darkened in the illustration. Consequently, the stroboscope tripping circuit is open and the light does not flash.

Gas pressure above the rings can be theoretically computed or actually measured in an engine; but this force is an undesirable variable to work with because of variation during the cycle and its discontinuity due to valve action and column-mass forces from the manifolding. To eliminate this variable, the engine head was replaced by a tank, shown in Fig. 3, with a volume approximately 100 times the piston displacement. The remaining 1% pressure variation due to the piston movement can be neglected.

To more fully understand the forces in operation during piston movement, piston velocity and acceleration for this glass cylinder engine at a speed of 2000 rpm were calculated and are illustrated in Fig. 4.

The deceleration force acting on the piston in the vicinity of the dead centers is of the order of 160 to 240 times gravity.

* "Piston Lubrication Phenomena in a Motored Glass Cylinder Engine," by Messrs. S. J. Beaubien and A. G. Cattaneo, Shell Development Co., was presented at SAE Summer Meeting on June 7, 1946.

Phenomena in a

MOTORED GLASS CYLINDER ENGINE

How and why oil is consumed in the combustion process has been perplexing engineers since the inception of internal combustion engines. Many theories have been advanced as to "where all the oil goes," but none have quite stood up under scrutinous investigations.

Recently conducted tests using a motored glass cylinder engine, described in this article, give evidence that the engineer is at last going to find the answer to his queries on the complexities of lubrication and oil consumption.

The composite picture of oil and piston ring movement obtained in these tests reveals a visual picture of what actually happens during cylinder lubrication and provides concrete instead of hypothetical data. One important discovery, made by Messrs. Beaubien and Cattaneo, is that a large part of the oil consumed by the engine is exhausted as the resultant forces in play during the exhaust stroke permit the top piston ring to move freely in its groove.

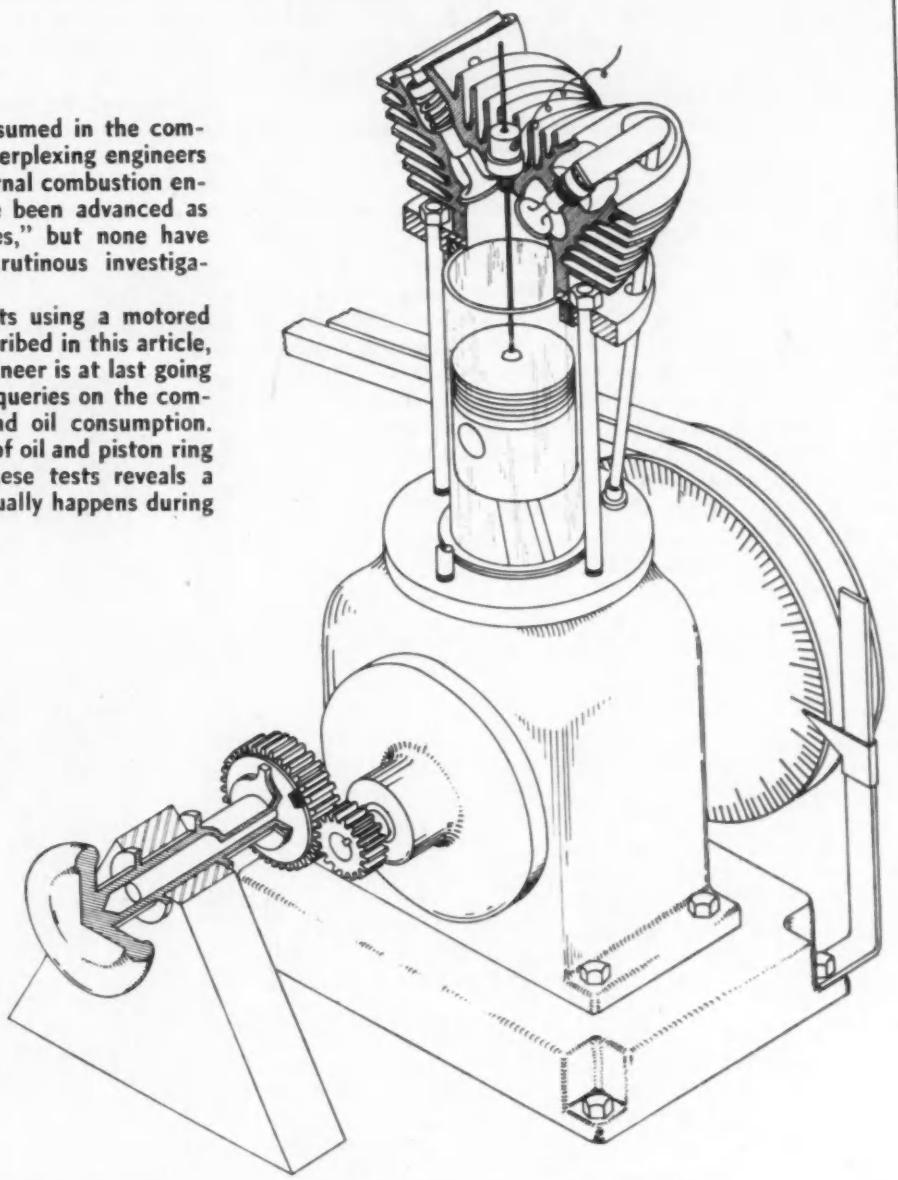


Fig. 1 – Schematic drawing of glass cylinder engine used to study effects of mechanical forces on oil behavior

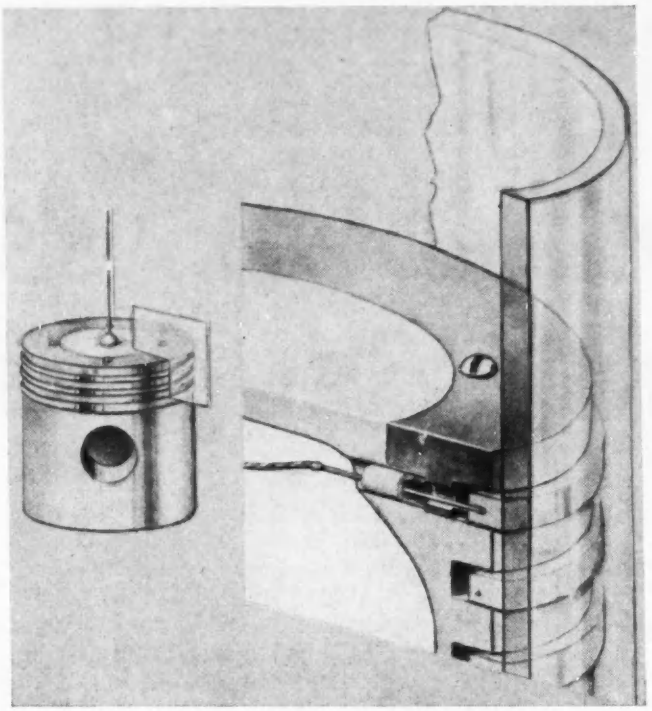


Fig. 2 – Details of electric circuit for determining the position of the top ring in its circuit

To obtain some idea of the effect of this force on oil distribution, a series of photographs was taken near bottom dead center. Although the deceleration force is nearly 50% greater at the top of the stroke than at the bottom due to the finite connecting rod length, the quantity of oil involved near the bottom of the stroke is greater and lends itself more readily to photographic observation.

Fig. 5A shows the piston at bottom dead center. Oil between the rings can be identified by the turbulence across the lands. It can be seen that the quantity of oil in the ring belt increases from the top land to the third land and that this oil is in motion, as evidenced by high turbulence.

The area directly beneath the oil ring is clear and undisturbed, indicating either absence of oil or – and this will be shown to be the more likely – a continuous unbroken film of oil. Close observation of Fig. 5A reveals that the oil in the gap of the second ring is apparently being pumped up across the second land. This is probably due to the viscous shear forces acting on the oil and created by relative motion between the piston and cylinder wall. In spite of the strong inertia force in the downward direction, some oil is being transferred upward across the belt.

Fig. 5B shows the piston on its upstroke at about 30 deg crank angle past bottom dead center. The area directly beneath the oil ring is no longer clear but shows a uniform belt of froth and small bubbles probably arising from cavitation or deaeration of the oil. The oil ring groove does not have oil return holes so that the froth could not be caused by air being drawn from the inside of the piston and out through the oil ring.

The only apparent explanation is that the quiescent area directly beneath the oil ring in Fig. 4A is covered with a continuous thick film of oil which fills the clearance volume between the piston skirt and the cylinder wall. During the initial part of the upstroke, Fig. 5B, the inertia force acting in the downward direction, coupled with the shearing force between the piston skirt and the cylinder wall, pulls the oil away from the lower edge of the oil ring. A vacuum is thereby created and the oil cavitates. Fig. 5B also indicates that the lands between the rings are comparatively free of oil.

Distribution of the oil on the piston at about 60 deg crank angle past bottom center is shown in Fig. 5C. The piston is moving upward with increasing velocity and decreasing acceleration force. The frothy region below the oil ring has extended farther down the skirt and the partial vacuum tends to drain the oil from the ring belt. Probably influencing the change in position of the boundaries which separate the different oil regions on the piston skirt is a change in the angle formed by the piston axis and the cylinder axis as the piston comes up on its stroke.

Fig. 5 shows the oil distribution on the piston skirt at three significant points in the cycle. The way in which different regions of the piston vary throughout the cycle is shown in Fig. 6. It is noteworthy that the cavitating region collapses at about 270 deg, which is close to the point of maximum velocity and zero acceleration.

When considering the significance of the deceleration force in the neighborhood of bottom dead center, the positions of the ring gaps become important. Fig. 7 shows the piston at about 10 deg before bottom dead center with the engine operating under the conditions outlined above, except that the engine speed was 1500 rpm in this case. Alignment of the top two ring gaps has permitted most of the oil between the rings to be drawn out along the cylinder wall. Successive strokes of the piston have distributed the oil circumferentially, leaving excess oil all around the cylinder wall.

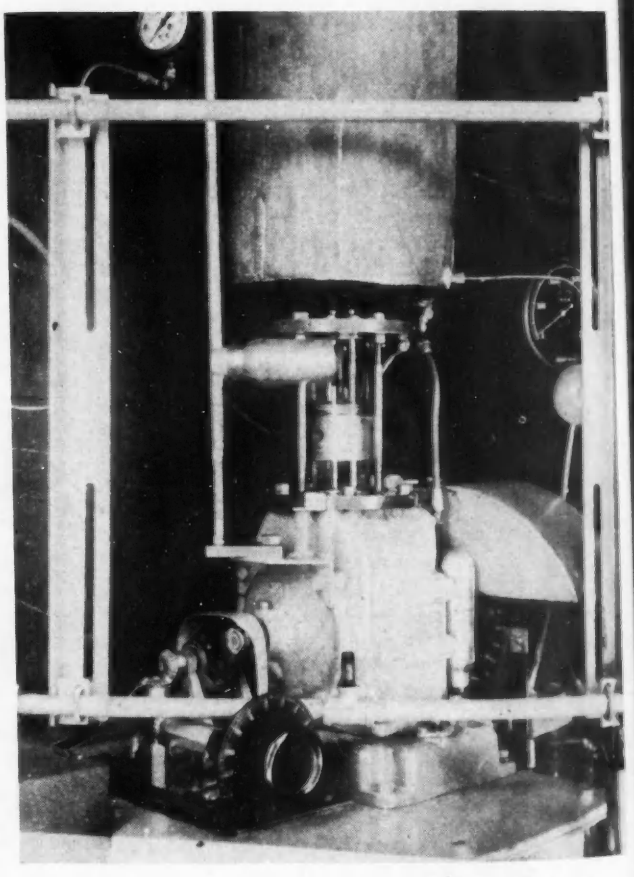


Fig. 3 – Glass cylinder engine with constant pressure tank replacing the engine head

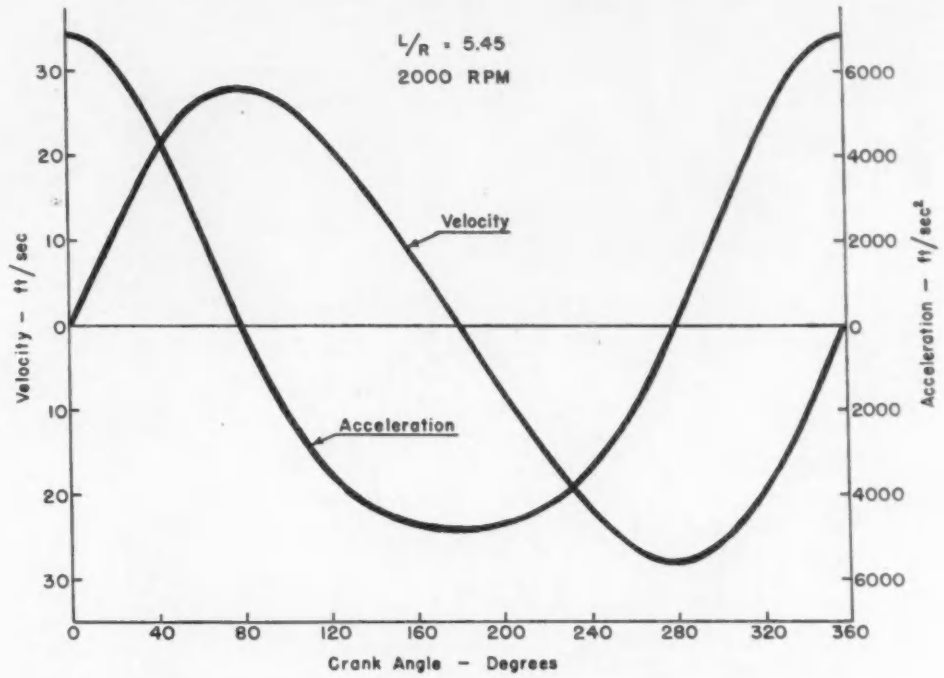


Fig. 4 – Velocity and acceleration diagram for piston of the glass cylinder engine

When ring gap alignment such as this exists, most of the oil is left on the cylinder wall before the deceleration force, and the consequent vacuum below the oil ring can draw the oil from the ring belt and project it down along the piston skirt.

Piston Ring and Oil Movement

A qualitative picture has been formed from numerous observations and photographs of the way in which the rings move in their grooves and the mechanism whereby the oil passes the rings from the oil sump to the combustion chamber. Fig. 8 shows the most significant points, with regard to top ring position and oil distribution, in a typical cycle of the motored glass engine. The oil is shown cross-hatched.

Moving of the piston from 0 deg – top dead center – to 90 deg is shown in Fig. 8A. Shearing forces and acceleration forces are acting together to keep the oil, scraped from the cylinder wall, in the groove behind the rings.

The piston is still moving up from 90 deg to 170 deg in Fig. 8B. Here the acceleration forces and the shearing forces oppose each other. The oil moves to the bottom of the groove because the piston is decelerating; it cannot run down over the lands because the relative motion between the piston land and the cylinder wall sets up shear forces which act as a simple viscosity pump and keep the oil in its groove. The ring remains on its upper seat because of the force of the side wall friction.

With the piston at bottom dead center, Fig. 8C, the velocity is zero; therefore, there is no side wall friction force on the ring and no shearing force acting on the oil. The acceleration

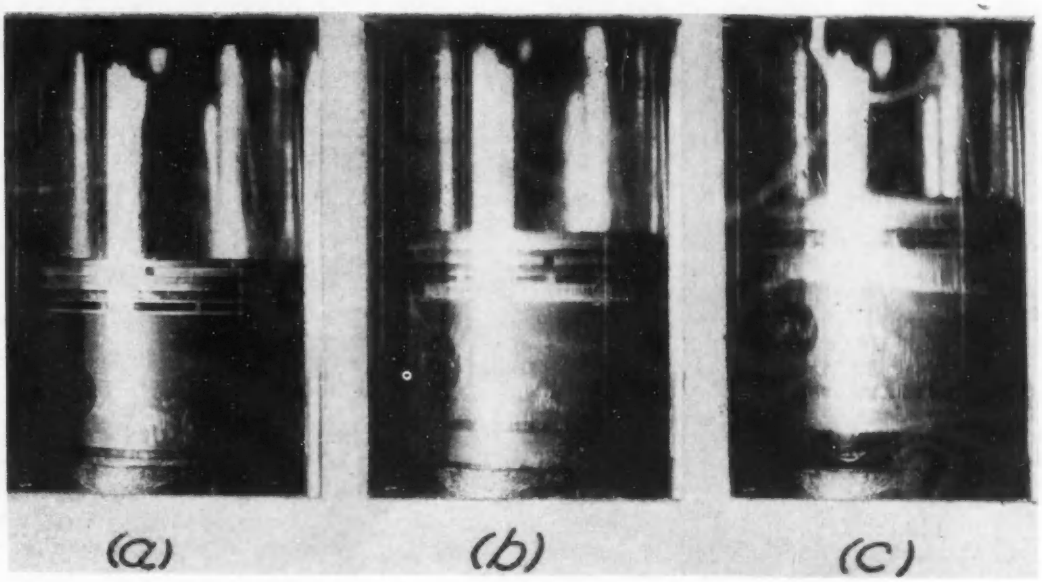
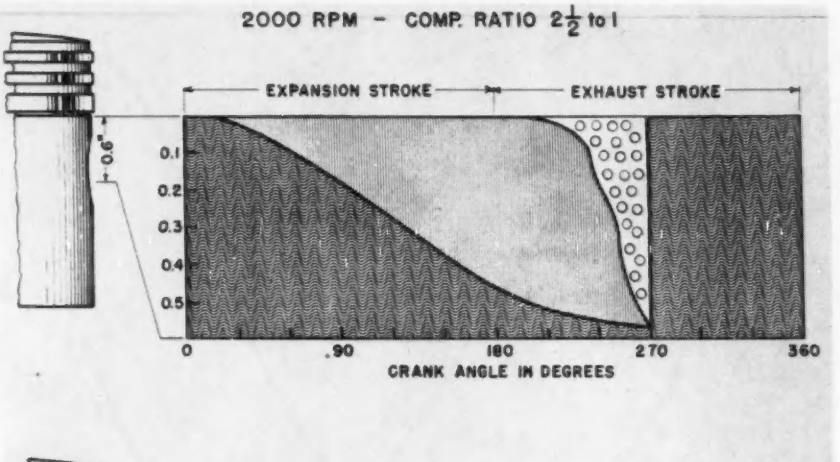


Fig. 5 – Distribution of oil at various positions of the piston. The piston is shown at bottom dead center in (a), on its upstroke at about 30 deg crank angle past bottom dead center in (b), and at about 60 deg crank angle past bottom center in (c)



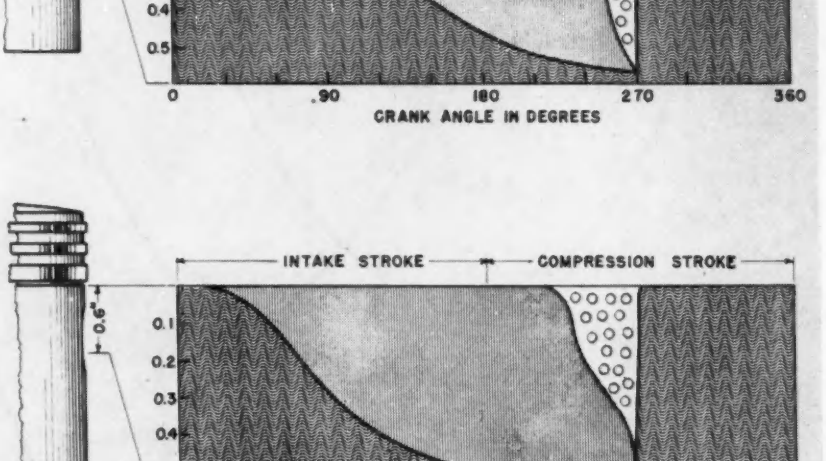
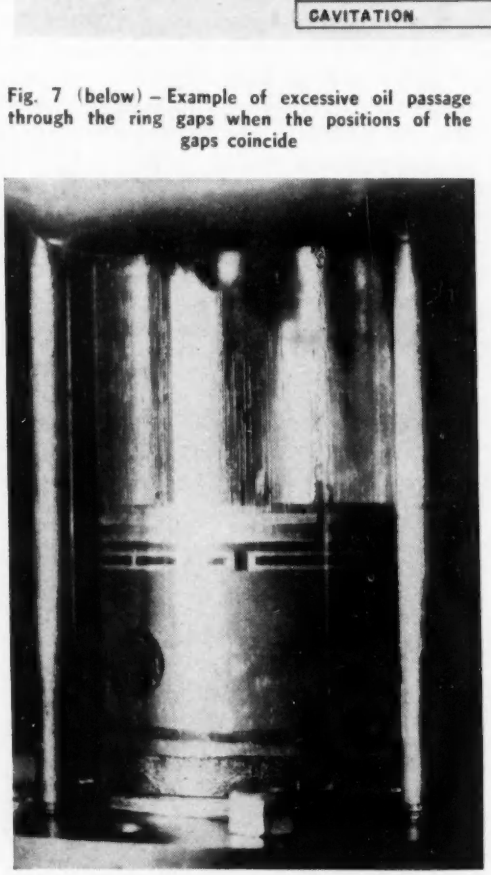


Fig. 6 – Characteristic oil patterns for different regions of the piston throughout the cycle

Fig. 7 (below) – Example of excessive oil passage through the ring gaps when the positions of the gaps coincide



force is near maximum at this point with the result that the oil runs out of the groove and the ring comes down against the lower seat.

As the piston enters the first half of its upstroke from 180 to 270 deg, Fig. 8D, both the shearing and acceleration forces act to keep the oil in the grooves behind the rings and to keep the ring on its lower seat.

In Fig. 8E, the piston is traveling from 270 to 345 deg. Again the shearing and friction forces due to velocity are opposed to the acceleration force. The oil flows to the top of the groove, but is prevented from running out by the viscous pumping action of the shearing force.

The top ring is changing from the lower to the upper crank seat at a 345 deg crank angle in Fig. 8F. This value is typical although the exact angle will vary with the operating conditions. The ring is actually squeezing the oil out of the groove space above the ring. Some of the oil is forced out over the top land and the rest is forced back into the groove. The position of the second ring is not shown here because the angle at which it changes groove seats was not determined.

Fig. 8G shows the piston about 2 crank deg later. The oil that was squeezed out over the piston land is being thrown into the combustion chamber.

With the piston at top dead center again in Fig. 8H, some of the oil from the second ring is migrating up to the top ring.

It is again emphasized that the sequence illustrated in Fig. 8 refers only to the motored glass engine. In a real operating engine, high pressures and temperatures will influence the oil distribution.

Condition at Seat Change

Photographs showing the piston just before and after the top ring changes seats near the top of the stroke, Fig. 9, reveal some interesting occurrences. In this case the engine head was replaced by a tank at atmospheric pressure and the speed was 1500 rpm. The top ring in the photograph at the left is still on its lower seat and a small quantity of oil can be seen creeping out of the groove and across the land. In the photograph on the right, the top ring has moved to its upper seat and sealed off any further passage of oil from the groove. The

spurt of oil that was flowing across the top land has passed into the combustion chamber.

It should not be inferred from this discussion that the upper ring pumps a quantity of oil equal to the volume displaced when it changes seats on each stroke. If such were the case, an engine like the Ford 60 with 0.002 in. ring side clearance would consume about a quart of oil per mile. The reasons an engine uses so much less oil are:

1. The space through which the ring moves as it changes seats is not always filled with oil.

2. The displaced oil is not completely ejected from the groove and thrown into the combustion chamber when the ring moves; some of it is forced back behind the ring.

3. Even though the oil is squeezed out of the ring groove, it does not necessarily reach the combustion chamber. Some particles will cling to the ring and return to the groove later on in the stroke.

An example of this is shown in Fig. 10. This photograph was taken near bottom dead center. The forces are reversed from the conditions near the top of the stroke, but the principles involved are the same.

Small droplets of oil can be seen clinging to the lower edge of the top ring. On the lower edge of the second ring, similar small droplets of oil have elongated and formed stringers which bridge the land between the rings and transfer oil between the second and third ring. Although the top and second ring are acted upon by the same acceleration forces, only the second ring transfers oil through the oil droplets.

Apparently the droplets on the top ring were small, and interfacial tension overbalanced the accelerating forces. The droplets on the second ring were a little larger. As a consequence of the larger mass-to-surface ratio, the accelerating

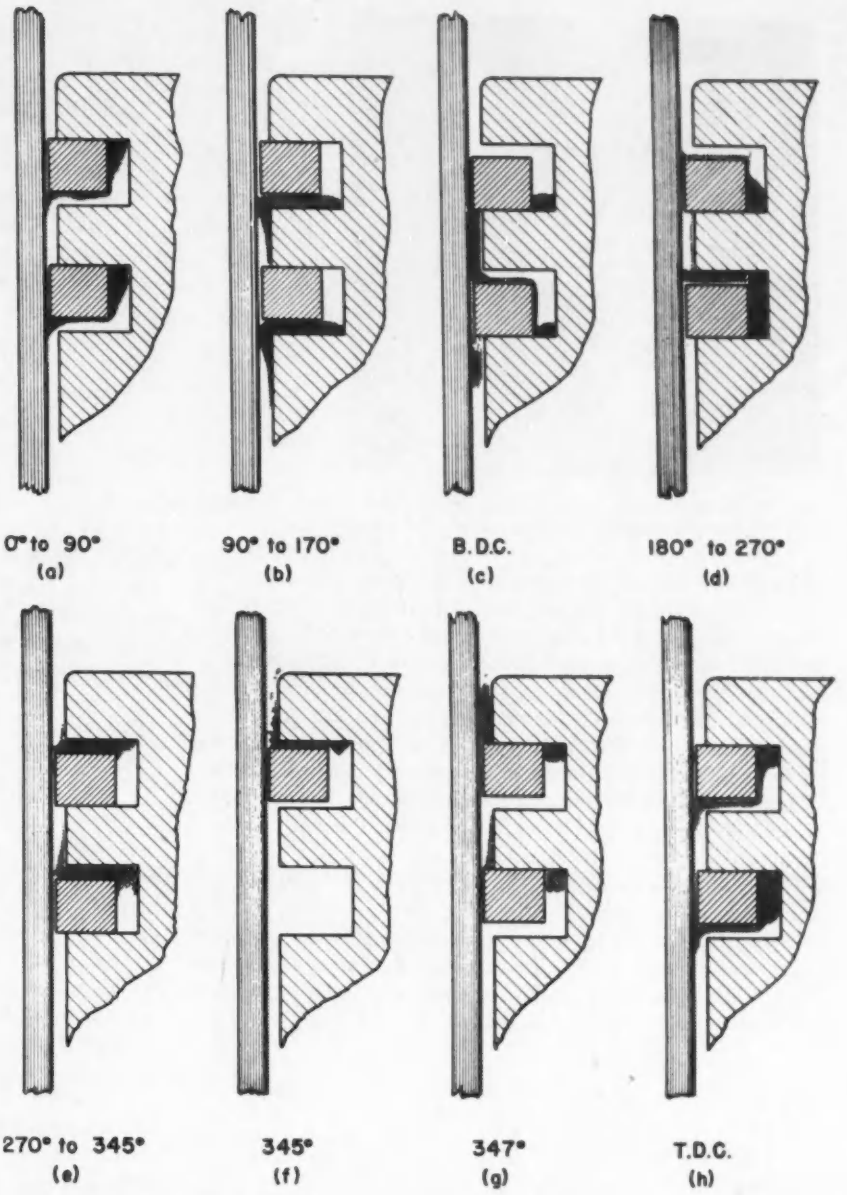


Fig. 8 (above) – Relationship of oil movement to ring position at the most significant points in a typical cycle of the motored glass cylinder engine

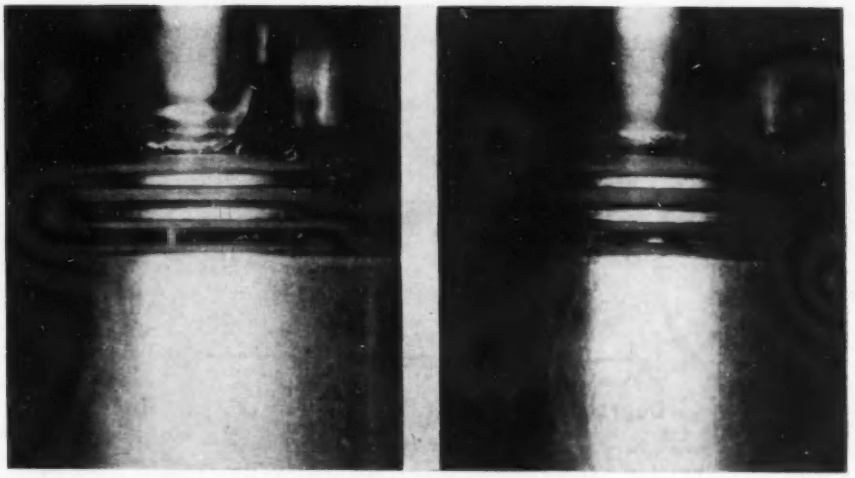


Fig. 9 – Photograph at left shows the piston just before the top ring changes seats near the top of the stroke and the photograph on the right shows the piston after the top ring has moved to its upper seat

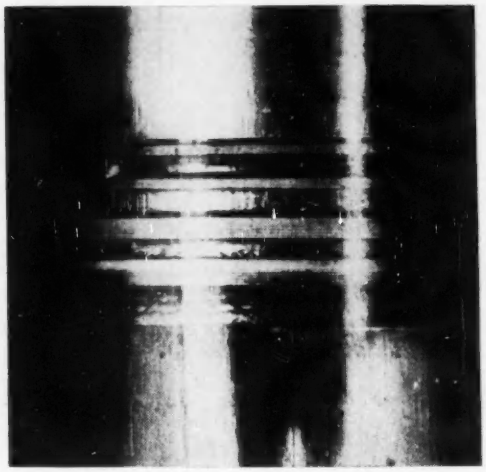


Fig. 10 – Example of the transfer of oil between rings by elongation of small drops

forces overbalanced the interfacial tension. The drops elongated and bridged the gap between the rings. It can be concluded that the oil in the groove must not only be squeezed out of the groove, but the droplets must be of sufficient size to permit the acceleration forces to overcome interfacial tension.

Several attempts were made to relate and analyze mathematically some of the variables such as combustion chamber pressure, acceleration forces, piston velocity, and oil viscosity in regard to their effects upon oil distribution. But it was not possible to make a valid analysis because of the complexity of the interdependency of the variables.

For example, a change in the acceleration force on the ring at a given crank angle would bring about a change in ring velocity, shearing force, quantity of oil in grooves, and possibly smaller change in oil viscosity and pressure between rings. Only in a rough qualitative way could some of the data be shaped into an intelligible picture.

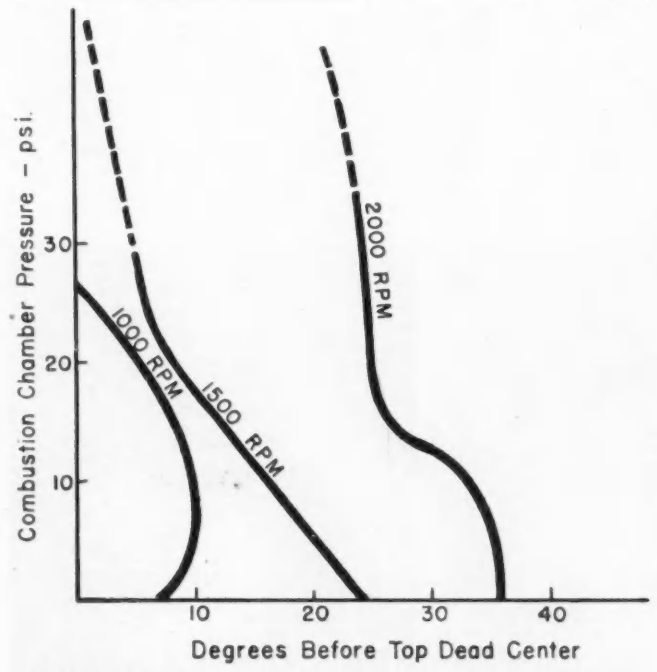


Fig. 11 – Relationship between ring equilibrium position and combustion chamber pressure for various engine speeds

The relationship between combustion chamber pressure and ring equilibrium position for various engine speeds is shown in Fig. 11. Ring equilibrium position, the point in the stroke where the ring changes from its lower position to its upper seat in the groove, is significant because of its relation to the passage of oil into the combustion chamber.

As might be expected, the ring left its lower seat earlier in the stroke with increasing engine speed and generally later in the stroke with increasing combustion chamber pressure; however, no simple relationship was found to unite these variables. The acceleration force on the ring varies as the square of the speed, and if this were the only change involved, the relationship would be readily detectable.

One of these additional variables is ring wall pressure. During the early part of the work on these tests, the top ring was broken. The new ring which replaced the broken one was found to require only one-fourth the acceleration force to lift it from its lower groove seat at a given crank angle. This seemed strange, since both rings had been previously well broken in by 40 hr of service operation in a conventional engine. The explanation may be that high oil consumption with well-worn rings is possibly due to the loss of ring tension and consequent pump action near the top of the stroke rather than to the passing of oil over the face of a worn ring.

Significance of Observations

Observations made during these tests may be oriented to form a composite picture of the oil consumption pattern in a normally operating engine.

First factor in the overall picture is ring motion. If in a normal engine a major portion of oil consumption occurs through the motion of the ring in its groove – as it does in the motored glass cylinder engine – then anything which would hold the ring on its lower seat near top dead center would reduce oil consumption. On the compression stroke the ring is kept on its lower seat by the compressed gases and by the additional pressure created by the firing of the charge near top center.

It appears likely, therefore, that a large part of an engine's oil consumption occurs through passage of the oil on the exhaust stroke when the top ring is free to move in its groove. Some evidence that this is actually the case may be gleaned from tests made on the effect of lubricating oil on detonation.

It is known that oils are pro-knock agents; if they are injected into the combustion chamber with the fuel charge, they seriously impair the detonation limited power output. However, when the same quantity of oil was permitted to reach the combustion chamber past the piston rings, by installing worn piston rings, it had practically no effect on the detonation limited power. Evidently this oil entered the combustion chamber on the exhaust stroke, and was blown out with the exhaust gases or deposited on the walls before the next firing stroke.

This is further borne out by experience with full scale aircraft engines in actual flight; it has been shown that in many cases high oil consumption gives long valve life, whereas low oil consumption leads to valve sticking and burning. It may be presumed that the extensive oil in the exhaust gases of engines with high oil consumption lubricates the exhaust valve and prevents its overheating.

In addition to normal passage of oil on the exhaust stroke, certain operating conditions favor oil pumping on the compression stroke. At low manifold pressure and retarded spark,

the compression and combustion pressures can be low enough to permit the ring to rise in its groove on the compression stroke even at relatively low engine speeds. Data taken on a small single cylinder engine indicate that oil consumption can be doubled by retarding the spark from 15 deg before top center to top center.

Another operating variable which can promote oil pumping on the compression stroke is engine speed. If speed is increased, the acceleration force will tend to lift the ring from its seat earlier in the cycle. The lower compression forces at this point in the cycle permit the ring to move even sooner than it would if increased acceleration force alone effected the change.

This may explain the often observed fact that at some definite critical speed, most engines appear to lose control over oil consumption. It is not intended that the usually accepted theories based on an increased wedge film across the ring face or on ring flutter should be discarded. It is quite possible that all these phenomena jointly are responsible for the sudden rise in oil consumption at high speeds.

DISCUSSION

By T. J. Nussdorfer,
National Advisory Committee for Aeronautics

THE mechanism of oil consumption presented in this paper is both interesting and reasonable. The methods employed, unlike those used in most previous investigations of cylinder oil flow, provide data which may be directly interpreted.

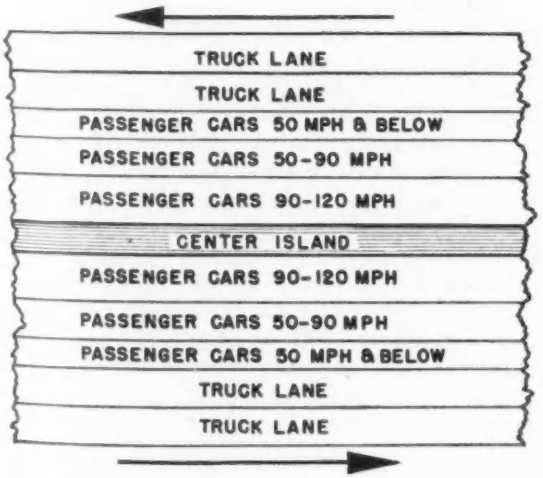
The effect of piston side thrust and the lateral motion of the piston do not appear to have been considered in interpreting the cause of the frothy area below the oil ring. While the rod length-stroke ratio employed was quite high – 5.45 – appreciable side thrust would be obtained at engine speeds of from 1000 to 2000 rpm; the piston assembly would move laterally near the top and the bottom ends of the stroke under the influence of this side thrust.

In addition to the acceleration and inertia forces on the oil, the froth that was observed could have been due to the lateral motion of the piston which would cause the oil to reverse its direction of circumferential flow twice each revolution. We have observed the oil film on either side of our glass sleeve to become discontinuous, or frothy, at the particular value of crank angle at which the piston changed its direction of side thrust. It would therefore appear that the "cavitation" could be explained by the lateral motion of the piston.

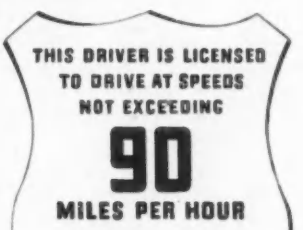
Sees Driving Skill Rated on 120-Mph Highways

Cars zooming along at 100 to 120 mph on superhighways will be common in the future, says A. M. Wolf, Automotive Consultant, if the automobile successfully meets the challenge of other means of transportation.

In his paper, "Future Automotive Possibilities," presented at the SAE Philadelphia Section on April 10, he predicts tomorrow's highways will be divided into three passenger-car lanes and two truck lanes. Each lane will carry traffic within a specified speed range.



Another of his predictions is that drivers will be graded according to their ability to drive at these speeds. A windshield sticker showing the driver's grading will – through adequate checking and penalties – keep incompetents from higher-speed lanes.



These stickers will have a distinctive color for each speed range and this data will be corroborated on the driver's license. Periodic reexaminations will detect any deterioration in driving, keeping highways safe by maintaining driving standards.

But the driver who thinks such speedy cars will enable him to leave pursuing state troopers in his dust is mistaken. Innovation of radio-controlled brakes – sealed and tamper-proof – will permit police to stop the runaway transgressor without even asking him to pull over.

Mr. Wolf also observes in his paper that increased vehicle taxation will shape public taste toward a more economically-operating automobile – a trend which manufacturers should heed.

Camera Techniques Expose

OIL FILM BE

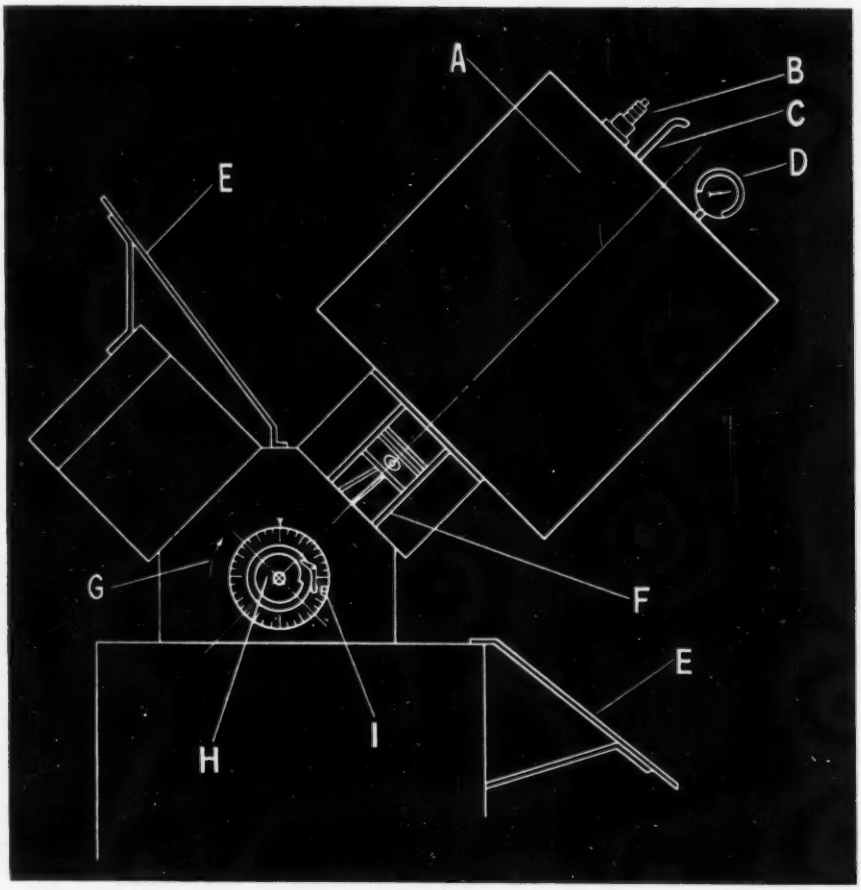


Fig. 1 – Diagram of engine equipped with glass cylinder. A, 2000 cu in. pressure tank; B, pressure relief valve; C, nitrogen inlet; D, pressure gage; E, camera bracket; F, pyrex glass cylinder; G, rotation; H, crankshaft cam; I, breaker points

PISTON inclination and lateral movement during the combustion process have – for the first time – been visually observed as the major factors influencing cylinder lubrication. Results of these studies confirm existing theories on cylinder lubrication and also reveal facts about oil film behavior previously unknown. They will guide designers of vehicle engines, reciprocating aircraft engines, air compressors, and other machines, NACA believes.

Making possible these disclosures are two new photographic techniques, using scattered and fluorescent lighting. The camera sees actual conditions occurring in the complete combustion cycle never before revealed by any other method.

In this, the first study of its kind in cylinder lubrication, it was revealed that:

1. Pistons are inclined in such a direction as to favor an oil wedge on the loaded side of the cylinder during the greater portion of the engine cycle. This fits the hydrodynamic theory.

2. Pistons move laterally from the major-thrust to the minor-thrust face of the cylinder under the influence of piston side thrust.

3. The amount of lubricant on the skirt varies with the relative angular position of the piston rings and with cylinder pressure.

4. Rate and direction of piston-ring rotation varies with cylinder-head pressure and engine speed. Rotation up to 1 rpm at an engine speed of 1000 rpm was observed.

5. When operating under load, the approximate thickness of an oil film on the piston-ring face is 0.0001 in. or less.

A description of the test facilities and an examination of the results fully explain these conclusions.

The visual study of the cylinder lubrication process was conducted at the NACA Cleveland laboratory with specially designed equipment. The 2-cylinder test engine, shown in Fig. 1, was a V-type 90 deg engine with one of the cylinder blocks replaced by a special unit that held a pyrex glass sleeve, 0.25 in. thick, allowing the piston to be observed without obstruction.

A large cylindrical pressure chamber having a volume of 2000 cu in. replaced the standard head. The ratio of the chamber volume to the piston displacement was such that only

BASED ON A PAPER BY **MILTON C. SHAW***
THEODORE J. NUSSDORFER*

BEHAVIOR

a 1.7% variation in the pressure occurred within the chamber as the piston moved from one dead center position to the other.

Initial study of such a simple constant-pressure system was considered advisable so that interpretation of the data would be straightforward. The pressure chamber was equipped with a pressure gage, a safety relief valve, and a fitting for connection to a nitrogen chamber.

A scale model of an aircraft type piston was lubricated by a cone of oil directed against the bottom of the sleeve. In all tests the inlet oil temperature was maintained at 80 F and the rate of flow was adjusted to 0.6 lb per min.

Another equipment set-up was required for investigating piston orientation. To interpret photographs of the oil film between the piston and cylinder wall, the variation of lateral position and inclination of the piston and cylinder wall had to be known.

Quartz fibers, 0.001 in. in diameter, were mounted above and below the piston, as shown in Fig. 2, to provide a reference line on the piston. By means of a cathetometer, the central element of the major-thrust face of the cylinder was found to be parallel to the collinear fibers. A very sharp highlight was obtained on each edge of the fiber by side lighting; the line along the left edge was used as a reference in all observations.

The relatively great distance of the reference line from the wrist pin magnified the linear displacement at the top and bottom of the piston owing to a small change in its inclination. Unlike various index lines ruled directly upon the piston, the quartz fibers remained very distinct when viewed by stroboscopic light at engine speeds as high as 1500 rpm.

Two measuring microscopes with scales reading in 0.001 in. units were mounted one above the other on the cylinder block and were focused upon the quartz fibers, as shown in Fig. 2. The microscopes were adjusted to give the same reading when moved to successive positions along a straight edge mounted parallel to the cylinder axis.

The oil film between a piston and a cylinder is so thin as to be invisible when directly illuminated. A relatively thick oil film, such as that obtained in a journal bearing under light load, may be rendered visible by means of a substance such as a dye added to the oil. Because the oil films encountered in cylinder lubrication even under light loads are extremely thin, a concentration of dye or other material to make the extent of the film visible would be extremely difficult to obtain. Two new methods of making very thin oil films readily visible, scattered light and fluorescent light, were used in this investigation.

The scattered light method of making invisible oil films visible utilized an arrangement of lights, baffles, and camera arranged as in Fig. 3. Energy from a capacitance of 8 microfarads at 2000 v was dissipated through a pair of General Electric flash tubes stroboscopically. The flash tube circuit was triggered by a set of automotive breaker points operated by a cam on the crankshaft, indicated in Fig. 1.

The scattered light principle used is the same phenomenon observed in the bending of a columnated light beam through a bent tube of plastic such as lucite. In this case, the light enters the space between the piston and the cylinder wall at a grazing angle when this space is completely filled with oil. A fluorescent dye in the oil increases the intensity of the light to be scattered. Some of the scattered light leaves the cylinder, resulting in a sensation of light at all points where there is an oil film and in darkness where no film exists.

In the fluorescent light method, the glass cylinder is directly illuminated by long wave length ultraviolet radiation from which all the visible light has been filtered – a beam of so-called "black light." Since all motor oils are fluorescent, a visible light is emitted from the oil film and only invisible ultraviolet rays are reflected from points at which there is no oil film. The intensity of the visible fluorescent light varies with film thickness and concentration of the fluorescent dye in the oil.

The fluorescent light method rendered an oil film very distinct to the eye; but the intensity of the fluorescent light was insufficient for a photograph to be obtained with a single stroboscopic flash of light. Good multi-flash photographs were obtained by using a brilliant stroboscopic source of ultraviolet light and a camera with a fast lens. Photographs were obtained with 25 flashes from two flash tubes using a camera with an f/1.9 lens, a Wratten No. 2A filter, and a fast pan-

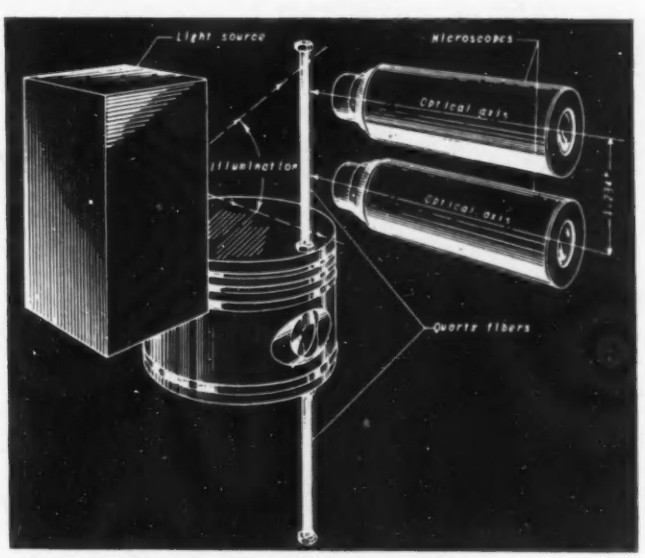


Fig. 2 – Apparatus for investigating piston orientation. Interpretation of oil film photographs necessitated a knowledge of the variation of lateral position and inclination of the piston and cylinder wall

*Paper entitled "A Visual Study of Cylinder Lubrication," by Messrs. Shaw and Nussdorfer, Aircraft Engine Research Laboratory, National Advisory Committee for Aeronautics, was presented at the 1946 SAE Summer Meeting, June 7, 1946.

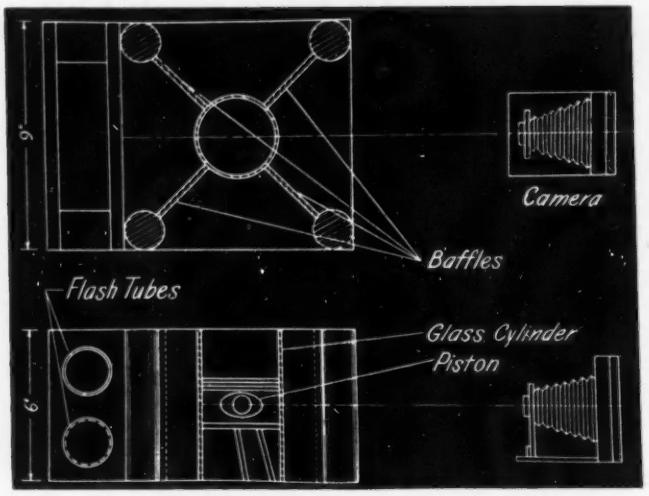


Fig. 3 – Equipment arrangement for photographing oil film by the scattered light method

chromatic film. The filter prevented reflected ultraviolet light from entering the camera lens – an important consideration because of the extreme sensitivity of photographic film to long wave ultraviolet rays.

Photographs of a stationary piston illustrating the difference in appearance of pictures taken by the scattered light and fluorescent light methods are shown in Fig. 4. The scattered light picture on the left was taken using a single flash from two tubes; the fluorescent light picture on the right was taken with 40 flashes.

The scattered light photograph shows only the oil film that touches both the cylinder wall and the piston. The fluorescent light photograph, on the other hand, shows the presence of all oil on the piston above a certain thickness, whether or not the film touches the cylinder wall. For example, the oil at point *A* in Fig. 4 was in the ring groove and did not touch the cylinder wall. The fluorescent light picture shows the presence of oil, but the scattered light photograph shows nothing at this point. Close examination of Fig. 4 also reveals that the fluorescent light method will not record the presence of as thin an oil film as the scattered light method. Therefore, the two methods are supplementary.

Proper interpretation of the photographic results and conclusions depends largely upon an understanding of the piston orientation studies. In the discussion on piston orientation that follows, a crank angle of 0 deg corresponds to the top-center position of the piston. The major-thrust face is considered to be the one upon which the piston rides on the down stroke.

Results of the quartz fiber investigations are given in Fig. 5, where the observed upper-microscope and lower-microscope readings are plotted against crank angle for two engine speeds at cylinder head pressures of 0 and 50 psi. Curves of the total side thrust, velocity, and acceleration of the piston are given for each test.

The vertical distance between the curves for the upper and lower microscope, at any crank angle, is a measure of the piston inclination. When the upper microscope curve is above the one obtained with the lower microscope, the piston was inclined with its crown toward the major-thrust face; when the reverse was true, it was inclined toward the minor-thrust face.

The mean position of the two readings relative to the 0-in. line determines whether the piston is on the major-thrust or minor-thrust side of the cylinder center line. For example, when the engine was run at 50 rpm with a cylinder-head pressure of 50 psi, in Fig. 5A, the piston was inclined with its crown toward the major-thrust face and was also closer to the major-thrust face at a crank angle of 100 deg.

Curves of Fig. 5 give the true inclination of the piston and a good approximation of its lateral position. They represent the loci of lateral displacements of points on the piston having a vertical spacing of 1.234 in. – the distance between the microscopes. Only an indication of the relative locations of fixed points on the piston are given since the microscope positions relative to the piston top change constantly with crank angle.

Observations were made at an engine speed of 50 rpm to simulate operation under very high load at a high engine speed without putting too much stress on the glass cylinder. A total piston side thrust of 100 lb at a 50 rpm engine speed is equivalent, as concerns lubrication difficulty, to a much higher load at a practical engine speed. Total piston side thrust with pressure in the cylinder reaches a maximum at approximately the same crank angle in Figs. 5A and 5B but the lateral motion of the piston is considerably greater at 50 rpm than at the higher engine speed. The piston runs approximately concentric with the cylinder when the resultant piston side thrust is small, but considerable lateral motion is noted in Fig. 5 under load.

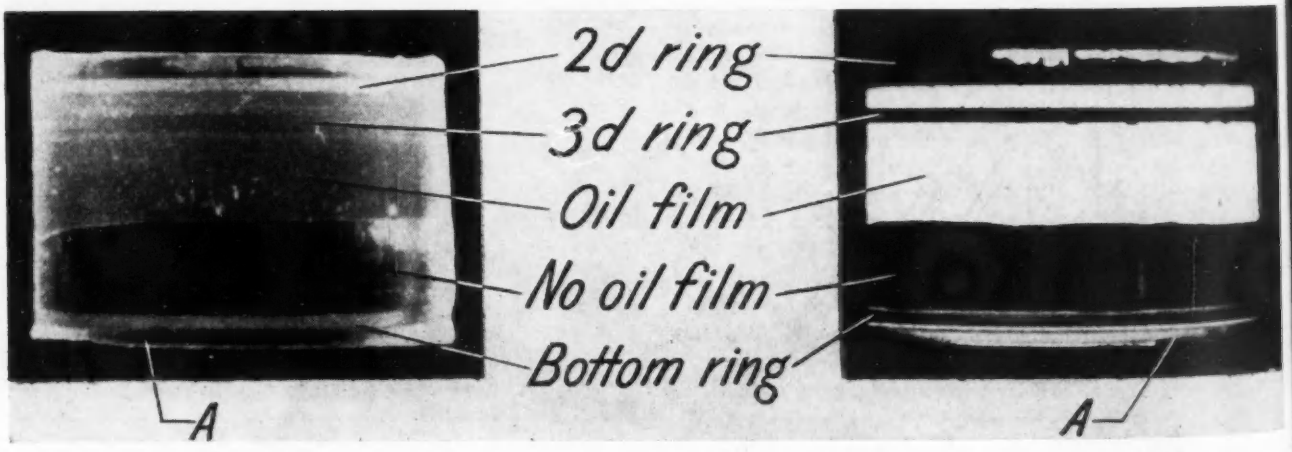


Fig. 4 – Comparison of photographs of a stationary piston through a glass cylinder by the scattered light method, at left, and the fluorescent light method, at right. Disclosures obtained by both methods are required to study cylinder lubrication behavior

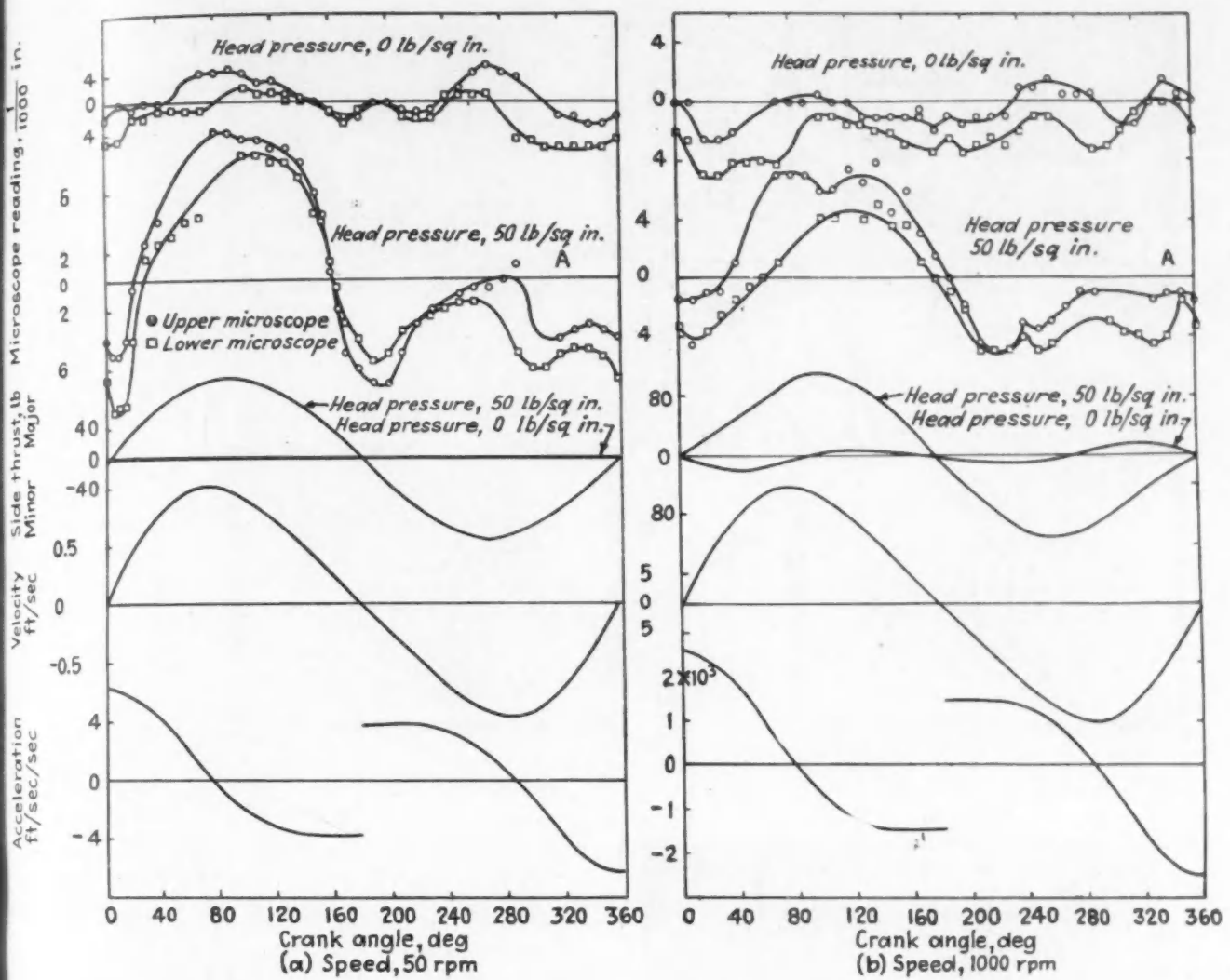


Fig. 5 – Variation of piston orientation with crank angle was obtained by microscope readings, using the apparatus shown in Fig. 2. These curves are essential in the interpretation of the oil film photographs

The piston is inclined with its upper end nearer the major-thrust face during the greater portion of both the up and down stroke. Such an inclination is essential if the piston is to operate hydrodynamically as a curved slider bearing. This inclination is in all cases equal to, or less than, 16 min of arc, and is generally less. These results bear out the hydrodynamic theory.

An inverted piston slope is evident from Fig. 5 in the region of bottom center, particularly at low speed. As the piston reaches bottom center, it moves toward the minor-thrust face, becomes vertical, and assumes a position with the piston top closer to the minor-thrust face than to the major-thrust face. As the velocity increases and an oil film is established, the piston returns to its normal inclination.

The piston did not move violently from one cylinder face to another as the total piston side thrust changed direction. Lateral movement of the piston occupied a considerable portion of the stroke. Start of this movement at top-center position lagged the reversal of piston side thrust, particularly at high engine speeds. And conversely, movement at bottom-center position anticipated reversal of side thrust, particularly at low engine speeds.

Photographs shown in Fig. 6 were obtained by the scattered light method at an engine speed of 1000 rpm and at cylinder-head pressures of 0 to 50 psi. Taken with the piston operating under light load, Figs. 6A and 6B show that oil is present on both sides of the piston at all times. The oil film is striated and broken into relatively small patches. The piston is operating close to the center of the cylinder, but somewhat closer to the minor-thrust cylinder face. The microscopic data confirm this interpretation. See point *A* of Fig. 5.

Photographs in Figs. 6C and 6D, taken at a 300 deg crank angle and 0 to 50 psi cylinder-head pressure, show representative views from the minor-thrust and major-thrust sides of the cylinder. Total piston side thrust was 80 lb in the direction of the minor-thrust face and it is evident from the photographs that the load was being carried on this face.

The load-carrying film in Fig. 6D is seen to have an approximately parabolic boundary. The corresponding piston-orientation data, given at point *A* in Fig. 5B, indicate the piston was nearer the minor-thrust than the major-thrust face, substantiating interpretation of the photographs. The upper-microscope reading is greater than the lower-microscope reading, which indicates the piston was inclined with its crown

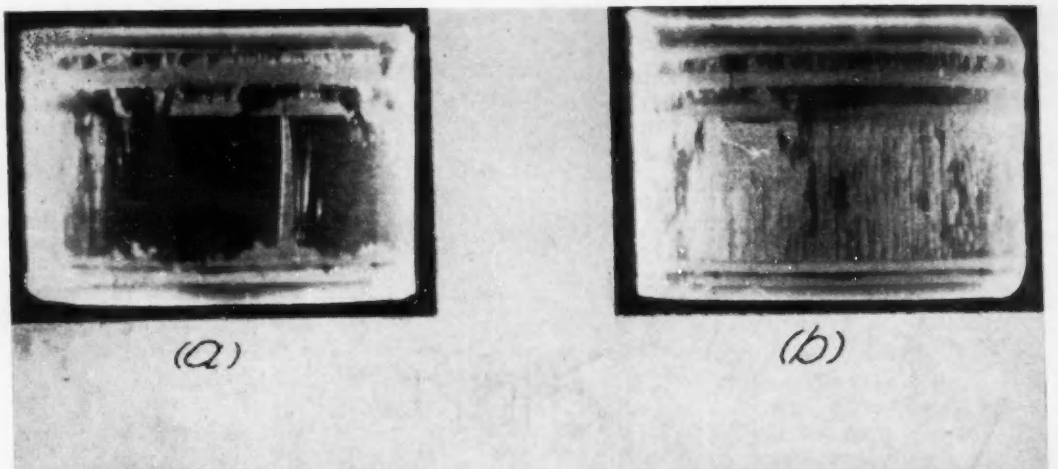


Fig. 6 – Photographs taken by the scattered light method at an engine speed of 1000 rpm and at cylinder-head pressures of 0 to 50 psi. Photographs in 6 (a) and 6 (b) were taken with the piston operating under light load

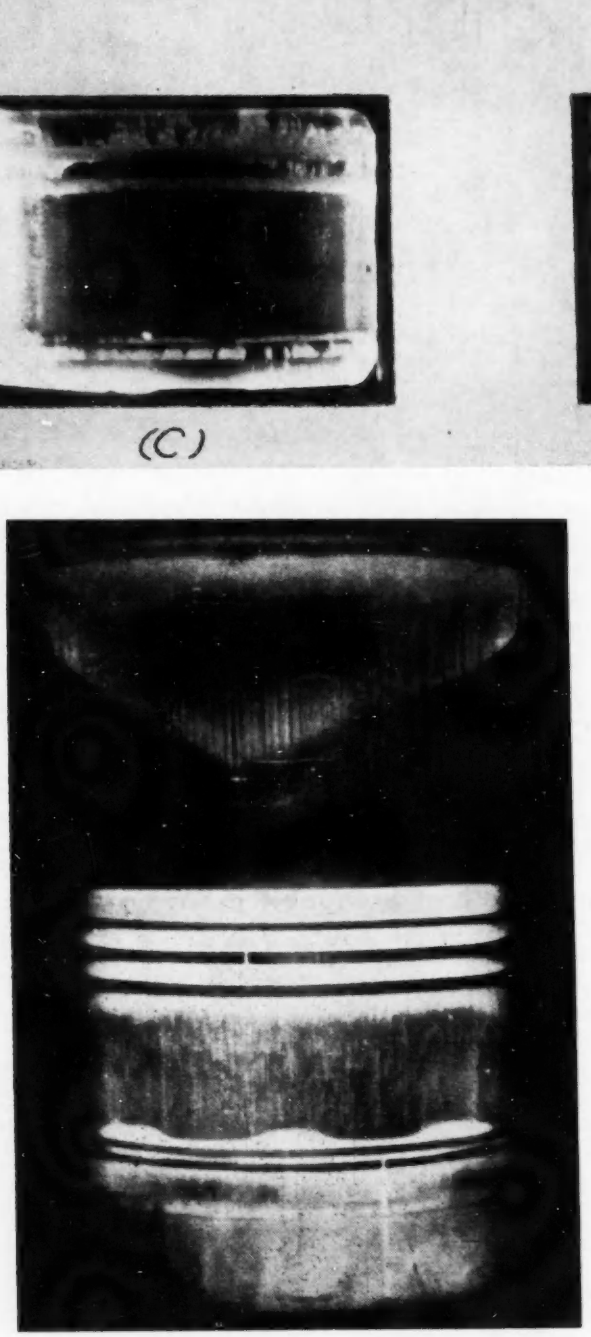


Fig. 7 – This fluorescent light photograph reveals a residual oil pattern at the top of the cylinder, offering additional evidence of the lag in the piston's lateral movement

nearer the major-thrust face. As a limited quantity of oil was available on the piston skirt, it is reasonable to assume that the upper film boundary would conform to a locus of constant film thickness.

These photographs indicate the basis for the conclusion that the amount of lubricant on the skirt varies with the relative angular position of the piston rings and with cylinder pressure.

Turning to the fluorescent light photographs, other interesting results were noted. The fluorescent light picture shown in Fig. 7 was taken from the major-thrust face. This photograph offers additional evidence of the lag in the piston's lateral movement. A residual oil pattern found at the top of the cylinder was evident only when there was sufficient side thrust to cause appreciable lateral piston movement. No such pattern was evident in cases without piston side thrust.

The top horizontal band of the pattern coincides with the top of the piston at top center and is probably produced by oil thrown from the piston crown upon its reversal. The lower V-shaped portion begins and ends at crank angle values approximately at the beginning and end of the lateral piston movement, as shown in Fig. 5. Oil was evidently squeezed from the top ring groove and the space above the ring as the piston moved toward the major-thrust face and was metered past the top edge of the piston. This metering action is attested by the fact that all striations visible in the pattern have counterparts on the top of the piston.

Fig. 7 shows no oil film between the rings and the cylinder face. Comparable scattered light photographs in Fig. 6, however, indicate that oil was present. When the intensity of the fluorescent light from the oil film beneath the rings was compared with that from films of known thickness, the piston-ring oil films shown in Fig. 7 were estimated to be 0.0001 in. or less.

Fillet Sealing Evolves Better Aero Fuel Tank

Digest of Paper by **A. S. BAKER**
Lockheed Aircraft Corp.

FILLET-MEMBRANE sealing represents a major stride in the soggy history of aircraft fuel tanks, declares Mr. Baker. Factors that contribute to a successful integral tank sealed at the fillets, he stresses, are:

1. Design and
2. Material.

Designs should require as few places to be sealed as possible – and those few should be accessible to hand operations. Metal-to-metal contact is desirable wherever possible and complicated structures should be avoided.

Sealing materials have been a bone of contention among engineers since the initial appearance of integral tanks. Lockheed developed a suitable fillet-sealing material – thiokol – only after extensive laboratory and dynamic testing. (More than 1000 kinds were tested throughout the industry in 1944 and not one would do the job properly.)

In the Lockheed laboratory tests, production suitability was determined by looking into such items as consistency, drying properties, ease of application, industrial hazards, and cost. Physical characteristics of water and fuel resistance, adequate tensile strength, pressure resistance, and low temperature flexibility had to be satisfied. Last laboratory phase dealt with chemical properties of corrosion during application and over a long period.

Dynamic testing of a full scale wing containing the fillet material covered the second half of the program. (*Paper entitled "Progress in Sealing Integral Tanks," presented at SAE Southern California Section, May 3, 1946.*)

Use of Rubber Excess Puzzles Postwar World

Digest of Paper By **J. L. COLLYER**
B. F. Goodrich Co.

COME the time when natural rubber production can supply all rubber demand – and that time seems nigh – we will face a dilemma, Mr. Collyer says:

Shall we abandon synthetic rubber production and endanger national security; or shall we continue it by government subsidy?

Mr. Collyer urges the second course. Minimum production and use of 200,000 tons of synthetic per year from government-maintained standby capacity of 600,000 to 700,000 tons per year is his idea of what is needed. That would preserve the needed know-how, he says, and keep alive development work in synthetic rubber and products.

Expansion of rubber uses appeals to Mr. Collyer as best hope for absorbing 1½ million ton surplus anticipated shortly. (He estimates: Production – 1,600,000 tons per year of natural rubber, 1,400,000 of synthetic. . . . Consumption – 1,500,000 tons per year.) Total surplus could be consumed if world use outside the United States could be boosted from 0.8 to 2.0 lb per capita each year. Americans themselves soon will be averaging 14 lb per capita. (*Paper entitled "Rubber! Where Do We Stand? Where Are We Going?," presented at SAE Annual Meeting, Jan. 7, 1946.*)

Extensive Tests Check Brake Lining Merit

Digest of Paper By **J. B. BASSETT**
Raybestos-Manhattan, Inc.

BRAKE lining manufacturers put new brake materials through wide and costly pre-marketing laboratory and road tests. These are based on the concept that a brake is a conversion machine; that it stops a vehicle by converting energy or momentum into heat – and that the life of drums and shoes depends upon proper dissipation of this heat.

First test of a new material is on a dynamometer. If it passes that, it goes on to controlled road tests. There, specially equipped trucks with accurate speedometers and distance recorders tell how effective the brake is in stopping the vehicle at different speeds, while other recording and visual instruments continuously measure the temperature of each shoe and lining.

Through with the road trials, the material is produced in small quantities. Then, back it goes again to the laboratory dynamometer. There its tests must check with earlier dynamometer results before the material proceeds to its fourth and final hurdle – extensive road testing under actual service conditions on fleets throughout the country. More than a year elapses between the first dynamometer tests and release of the material for full-scale production.

Through these careful procedures, Mr. Bassett says, industry has developed heavy-duty materials, unusually stable in frictional characteristics, to withstand temperatures greater than any existing today in conventional drums. The long life and faithful service which the materials give the customer were born of the stringent checks and counter-checks made before the product hit the market. (*Paper entitled "A Resume of the Development of Heavy-Duty Friction Material for Power Brakes," presented at SAE Baltimore Section, March 14, 1946.*)

Modern Criteria Set For All New Highways

Digest of Paper By **H. S. FAIRBANK**
Public Roads Administration

ADAPTION of facility to function will keynote the national highway program under the Federal Aid Highway Act of 1944, promised Mr. Fairbank. Design standards proposed for future road construction by the Interregional Highway Committee emphasize safety and efficiency of highway travel.

These standards of the future call for wide rights of way – 224 to 300 ft – to accommodate vehicles standing clear of traffic. They prescribe flat-sloped embankments to reduce danger of departure from the road; also spiraled and superelevated curvature for safe negotiation at anticipated speeds.

Specified for roads carrying less than 2000 vehicles per day are two 12-ft lanes and, for traffic volumes above 15,000 in rural areas and 20,000 in urban areas, six lane divided highways are recommended.

Also contemplated is elimination of stop-and-go signals on interregional highways and a minimum of cautionary signaling. Design criteria will be based on free and safe movement of traffic at a 20-year estimated level.

Disappointing to vehicle designers is the proposal that pavements will be designed for a maximum axle load of 18,000 lb. (*Paper entitled "Highways of the Future," presented at SAE Annual Meeting, Jan. 8, 1946.*)

M·A·T·E·R·I·A·L·S P

Industrial advancement has been recognized as a marriage of the test tube and drafting board. Modern products from the aluminum kitchen pot to the jet propulsion airplane could not have been designed and produced were if not for new materials developed by the chemist and metallurgist.

Material developments promising to enhance the automotive industry's future have been revealed at recent SAE meetings.

INSPECTION

Digest of Paper By **DONALD ERDMAN**
Triplett & Barton, Inc.

SUPERSONIC sound waves have been harnessed to inspect forgings, rolled stock, extrusions, and non-porous castings, reports Mr. Erdman. In describing the process and its potentialities, he said that:

Short bursts of supersonic sound waves sent into metal will show any defects such as cracks or voids. The defects reflect the pressure wave group back to the sending source. There they are received, amplified, and shown on a cathode ray tube as dips or deflections in a horizontal line. A quartz crystal about the size of a dime sends and receives the sound waves.

In inspecting an axle or a long extrusion, for example, the operator places the crystal at one end of the part and observes on the cathode ray tube two dips in the line – one representing the transmitted signal and the other an echo from the far end of the axle. Any defects between the two axle ends would show up as additional deflections on the cathode ray tube trace. Length of the trace is accurately calibrated in terms of the length of the part being inspected so that a fault can be easily located.

Variables such as sound wave frequency, methods of acoustically coupling the crystal to the part being examined, and electrical characteristics of associated equipment must be adjusted in accordance with anticipated grain size, surface contour, and dimensions of the part. Generally the higher the wave frequency, the finer the detail observed. Fifteen megacycle waves give excellent sensitivity on magnesium castings and forgings.

Aluminum castings are usually too porous to permit short wave lengths to penetrate, although large aluminum forgings and extrusions are readily inspected. New high temperature alloys and 4130 and 4140 steels will give indications from small inclusions, holes, or cracks through several feet of metal.

Tests made on flash and pressure welds show that much information can be obtained about gross defects in the weld. Fig. 1 shows a flash weld trace. Occasionally sound waves will neither penetrate through the weld nor echo from it, indicating a condition tending to disperse the waves. This condition has been observed in a high alloy forged bar when the new wave travels through metal of fine grain structure and then reaches a decarburized area with a large grain pattern.

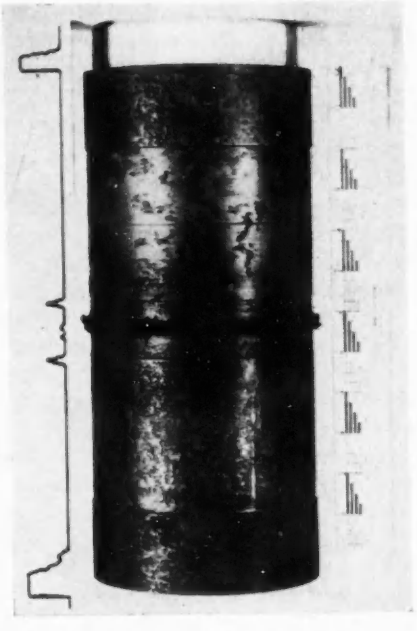


Fig. 1 – Flash welded tube with image of supersonic sound waves from cathode ray tube. Deflections near the center of the tube are from the machined shoulders and from grain upset in the flash weld

Prospects are good that a quick and economical method of checking heat treatment can be developed with an easily adjustable sound wave frequency. Sound penetration drops from several feet to less than an inch when 24S alloy is burned during heat treat. *(Paper entitled "Supersonic Inspection of Materials and Parts," presented at SAE Southern California Section, May 3, 1946.)*

MAGNESIUM

Digest of Paper By **J. C. DEHAVEN**
Battelle Memorial Institute

MIRACLES wrought by modern metallurgy converted magnesium from a "firecracker" material to a structural metal that bids for a ranking position among current aircraft materials. In highlighting the major improvements which now make magnesium so practical, Mr. DeHaven shows that:

Before magnesium's all-important virtue of low weight could be converted to use, the following undesirable properties had to be eliminated:

1. Inflammability,
2. Low corrosion resistance; and
3. Poor casting qualities.

Use of magnesium ribbon and powder for flares and incendiaries aroused fear in layman and metallurgist alike that the material was unsafe around the house – even in bar form. Almost any metal in a finely divided form can be made to burn and magnesium is no exception. An alloying addition recently developed exhibits remarkable inhibiting effect on the metal's burning characteristics. So potent is this additive that magnesium sheet – the most inflammable structural form – is not affected to any greater extent than sheet steel when subjected to incendiary ignition.

New cast-magnesium alloys now being developed demonstrate such desirable elevated-temperature properties that it is expected these alloys will find applications in gas turbine compressors, pistons, and cylinder heads.

Second obstacle to acceptance of magnesium as an engineering material – excessive corrosion – was often the result

Pace Design Progress

ot melting fluxes becoming entrapped in the metal and carried over in the final product. These fluxes contained chlorides which would effloresce during atmospheric exposure and cause severe corrosion. Superior fluxes and improved metal-handling have eliminated these flux inclusions and their corrosion-promoting effects in magnesium alloys of today.

Found acting as a catalyst for salt-atmosphere corrosion were impurities in magnesium alloys. Especially harmful is iron; copper, nickel, and silicon are also undesirable contaminants. Advanced production control methods made it possible to keep these impurities at such low levels that present magnesium alloys are not only extremely resistant to ordinary atmosphere corrosion, but may be considered corrosion-resistant materials for exposures in salt atmospheres.

Surprising as it may seem, salt-atmosphere corrosion resistance properties of the alloy were bottlenecking magnesium casting production during the war. Foundry methods – until recently – could not properly cast low-impurity magnesium. As a result, Government specifications were changed to require higher zinc content in the alloy to facilitate casting, but reducing at the same time resistance to salt-atmosphere corrosion.

New developments in foundry technology have pointed the way to commercial production of low-impurity alloys. These low or zero zinc-containing alloys now have better corrosion-resistance characteristics, require fewer risers, and are easier to heat treat than higher zinc alloys. Techniques which permit production of high-impurity alloys show promise of cutting production costs. These developments make possible cheaper and more corrosion-resistant magnesium castings of high quality.

Typical weight-saving applications to which current magnesium alloys lend themselves are: passenger, cargo, and bomb-bay doors; horizontal stabilizers; bulkheads and partitions; furniture; wheels; brakes, and miscellaneous engine and supercharger parts. *(Paper entitled "The Development of Magnesium Alloys as Aircraft Materials," presented at SAE Aeronautic Meeting, April 4, 1946.)*

RUBBER

Digest of Papers By **E. W. STEIN**
Firestone Tire & Rubber Co.
and **EARL GULICK**
B. F. Goodrich Co.

TO skeptics who think synthetic rubber an expensive and passing fancy of the late war, both Mr. Gulick and Mr. Stein argue that:

Present man-made rubbers have very good qualities and are getting more important in the rubber program. They excel natural rubber in many ways. For example, synthetics rate well above the natural product in aging resistance in sunlight, oxidation, and static aging. Some types resist swelling caused by mineral oil and gasoline whereas natural rubber does not. One synthetic even resists hydro-carbon aromatic solvents and acids. As for electric resistivity and electrical insulation properties, several synthetics are at least equal to the natural product.

In tires, Butyl tubes have held air for an indefinite period, ending the long search for a tube that will not allow air to seep out. But even more important is the progress made in tire casings.

Man-made rubber treads are equal to natural rubber treads in resistance to cracks induced by flexing. (Once started, however, cracks tend to grow more rapidly in the synthetic tread.) At high speeds the synthetic tire performs as well or even better than the pre-war casing. High speed laboratory tests of recently developed tires show them 40% better than the average pre-war tire, which means longer mileage from the postwar tire.

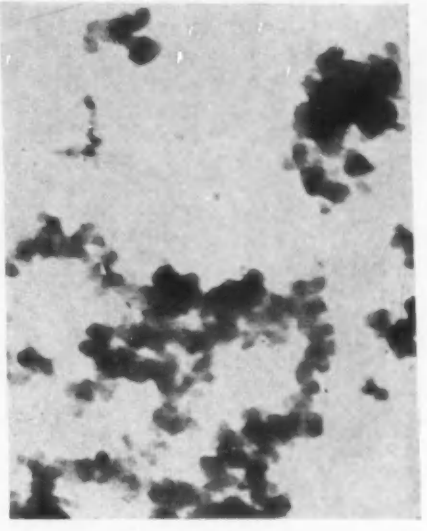


Fig. 1 – High modulus black used as a stiffening agent in rubber compounds magnified 7000 diameters

The hysteresis or internal friction loss, characteristic in man-made tires, is said to require a little more power to keep the automobile rolling and adds up to $6.00 per year in higher fuel consumption. Rubber technologists point out it is now possible to produce a polymer running cooler – or possessing a lower hysteresic index – than natural rubber. These cool-running polymers may be developed to become the tire rubber of the future.

Obviously synthetic and even natural

Turn to p. 97

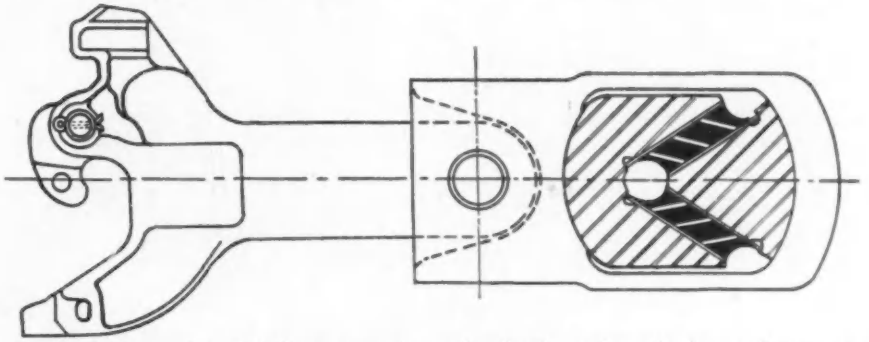
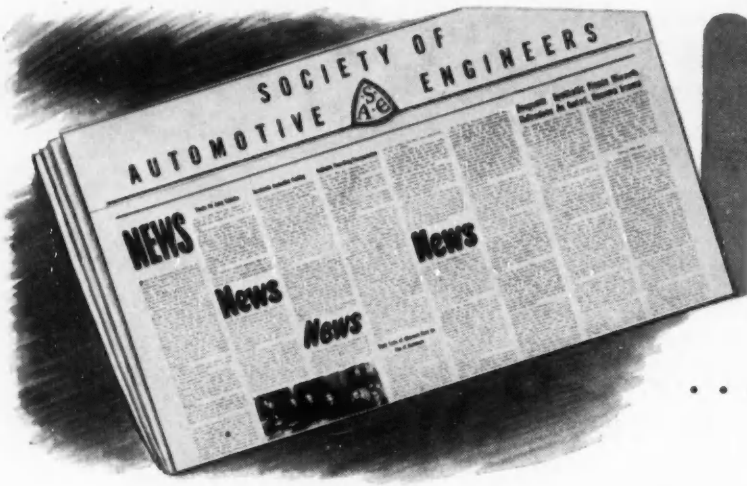


Fig. 2 – Rubber-cushioned draft gear on a locomotive drawbar and coupler is one of many new applications being found for rubber



News...

...OF THE SOCIETY

Huge Effort Concentrated On SAE National Meetings

THOUSANDS of man-hours have been devoted by more than 300 SAE Meetings Committeemen and Section officers to developing plans for the most important series of fall and spring technical meetings in the Society's history.

As we go to press, detailed arrangements for the National Aeronautic Meeting, with its large Aircraft Engineering Display in Los Angeles, Oct. 3 to 5, have been completed. The first postwar SAE National Production Meeting, Oct. 14 in Cleveland, has been finalized.

Programs of the SAE National Transportation & Maintenance Meeting (Chicago), Oct. 16 and 17, the National Fuels & Lubricants Meeting (Tulsa), Nov. 7 and 8, and the SAE National Air Transport Engineering Meeting (Chicago), from Dec. 2 to 4, have been rounded out. Finishing touches are being put on these programs and detailed arrangements by the Activity Meetings committees and officers of the local sections involved.

Including these remaining SAE national meetings of the current calendar year, a total of 212 technical papers will have been presented during 1946. This compares with 175 in 1944 – an increase of about 21%. (The increase over 1945 is 168% – because wartime travel restrictions during 1945 brought cancellation of six national meetings. The 85 papers originally scheduled for the cancelled national gatherings were presented before various SAE Sections as Local War Emergency Meetings.)

The total registrations at the 11 National Meetings in 1946 is expected to reach nearly 10,000, as compared with the 8396 registered for the nine 1944 National Meetings. Figures for 1945 are incomplete, and because of travel restrictions, would not be comparable.

Members of the 11 SAE Activity Meetings Committees, together with the Engineering Materials Meetings Committee, have been working for months on plans of the 1947 Annual Meeting, scheduled for the week of Jan. 6 in Detroit. Present indications are that this will be the largest program of any SAE Annual Meeting in history, according to SAE Past-President Ralph R. Teetor, chairman of the Meetings Committee.

One of the problems has been to arrange the schedule of sessions in such a way as to reduce interference to a minimum. This interference is caused by the necessity of scheduling simultaneous sessions, and in several cases three simultaneous sessions are tentatively planned.

Whittle Wins Guggenheim

THE 1946 Daniel Guggenheim Medal for Achievement in Aeronautics will be awarded to Air Commodore Frank Whittle, RAF, "for pioneering the development of turbo-jet propulsion of aircraft." The board of award is composed of a representative of the United Engineering Trustees, Inc., and three representatives each from the American Society of Mechanical Engineers, Society of Automotive Engineers, and the Institute of Aeronautical Sciences, together with American recipients of the medal. SAE members of the board are R. D. Kelly, SAE Past-President Mac Short, and G. A. Page, Jr. Previous medallists include Orville Wright, William Edward Boeing, Donald W. Douglas, Glenn L. Martin, James H. Doolittle, and Lawrence D. Bell. Only 40 years old, Commodore Whittle organized a small firm 10 years ago to manufacture his invention, the first practical turbo-jet engine. This work was later taken over by the British Government, and during the war he was in this country, incognito, on a liason mission. He has described his development before several SAE Sections.

Air Commodore Frank Whittle

SAE Service Is Expanding

MORE than 100,000 copies of hundreds of SAE engineering reports and technical papers have been distributed by the SAE Special Publications Department, established 15 months ago by the SAE Publications Committee. The department was suggested to increase the dissemination of technical information to automotive engineers.

This is the sum of more than 40,000 copies of about a dozen SAE technical committee reports covering a wide range of automotive subjects, and more than 60,000 copies of several hundred SAE Meetings papers.

Meetings papers are stocked for at least a year after presentation, and their availability is announced by check lists, revised to include new papers, periodically in the *SAE Journal*. A further service inaugurated recently is the inclusion of a special order-blank check list of meetings papers to be presented at a given national meeting with the program which is sent to each SAE member.

Many of the technical reports, according to their sponsoring committees within the SAE structure, are of lasting value.

In considerable demand during the past year, and with prospects of being wanted for some time to come, for example, has been the report on Engine Deposits: Prevention and Removal. This was prepared by a special technical committee of the SAE Transportation & Maintenance Activity Committee, and has reached a total distribution of 32,000. A number of vehicle companies and petroleum refiners bought copies of this report in quantities of 1000 and more for distribution to mechanics handling their products.

The comprehensive study on Evaluation of Effects of Torsional Vibration has been distributed to nearly 1000 engineers to date, despite its highly specialized character. Copies have gone to England, Sweden, Norway, China, France, Holland, Brazil, Australia, and Canada.

Nearly 2000 copies of reports on springs, originally developed at the request of the Army Ordnance Department, have been distributed.

Six reports on ferrous foundry procedure, including three on repair of defective castings, were distributed, and a reprinting was ordered of these six documents combined as one. These have reached a total distribution of 1400 copies to date.

More than 1200 requests have been received for another SAE engineering report on Process Control of Aluminum Castings.

This extension of SAE technical service is directed by the Publication Committee, of which William S. James, director of automotive research, Ford Motor Co., is chairman. His colleagues on the committee are J. M. Campbell, General Motors Research Division; A. T. Colwell, vice-president, Thompson Products, Inc.; John G. Lee, assistant director of research, United Aircraft Corp., and D. G. Roos, vice-president, Willys-Overland Motors, Inc.

Other members on this committee are: B. B. Bachman, Autocar Co.; C. H. Bolin, Pacific Telephone & Telegraph Co.; R. W. Brown, Firestone Tire & Rubber Co.; Dr. H. R. DeSilva, Surplus Property Administration; Dr. H. C. Dickinson, National Bureau of Standards; R. D. Evans, Goodyear Tire & Rubber Co.; F. L. Faulkner, Armour & Co.; H. F. Hammond, American Transit Association; F. C. Horner, General Motors Corp.; P. J. Kent, Chrysler Corp.; Prof. W. E. Lay, University of Michigan; Dr. Lemon, U. S. Rubber Co.; A. A. Lyman, Public Service Coordinated Transp.; Prof. R. A. Moyer, Iowa State College; T. L. Preble, Tide Water Associated Oil Co.; C. A. Roberts, Ohio State University; V. J. Roper, General Electric Co.; K. D. Smith, Worcester Wire Works Div.; Prof. K. W. Stinson, Ohio State University; S. J. Williams, National Safety Council, Inc.; and J. F. Winchester.

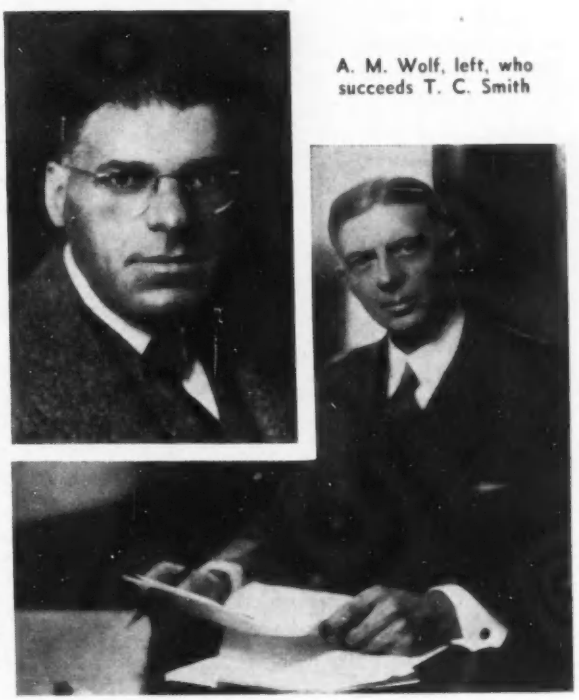
Wolf Succeeds Smith As SAE Group Head

A CERTIFICATE of commendation in grateful appreciation of T. C. Smith's inspiring leadership and long service in promoting safe and efficient use of motor vehicles on the highways as Chairman of the Highways Research Committee, was presented to him on Sept. 19 by Dr. Burton J. Lemon at the Metropolitan Section meeting held at the Hotel Pennsylvania.

Mr. Smith, who served as Chairman of the Highways Research Committee since its inception in 1933, resigned in June of this year because of pressure of other responsibilities. However, he will continue to be an active member of the committee. Austin M. Wolf, who has been a very active member on various other SAE committees has been elected chairman.

This committee conducted an extensive study, at the request of the ICC, on technical phases covering the relation between motor vehicle taxation and highway costs; assisted the American Standards Association in preparing background material for the ICC Manual on Motor Carrier Safety Regulations; and made studies from time to time of regulatory and safety problems presented by State Highway Departments including routine State inspections of motor vehicles.

At present the committee is active on two new projects entitled "king pin offset" and "method of measuring friction between the tire and the road."



A. M. Wolf, left, who succeeds T. C. Smith

SAE Student Work Begins

WITH the appointment or election of a score of Section Student Committee chairmen, this 30 year old program of the Society is getting under way after the partial interruption caused during the war by the Army-Navy student program.

Just before the war there were 15 SAE Student Branches in colleges from coast to coast. The indications are, according to Chairman R. B. Sneed of the SAE Student Committee, that a number of other colleges will be added to the list and that student enrollment will enjoy a healthy growth this fall and spring.

The vitality of SAE technical meetings is counted upon to bring to enrolled students a wealth of engineering information on all phases of automotive research and development. Enrolled students are supplied with copies of the *SAE Journal,* and hold meetings on their respective campuses to discuss engineering topics of interest to them.

Local SAE Sections provide speakers upon request. Frequently headquarters has been able to suggest technical moving pictures for showing at these Student Branch meetings. Each of the Student Branch has a faculty adviser who stimulates these campus meetings programs.

Section Student Chairmen are:

Buffalo, Benjamin Fuente; Chicago, N. C. Penfold; Cincinnati, Russell T. Howe; Cleveland, Robert Cummings; Detroit, R. B. Sneed and E. K. Harris, his assistant; Indiana, Joseph Liston; and Metropolitan, Robert R. Templeton.

Mid-Continent, Harris J. Elder; Milwaukee, R. L. Switzer; New England, Arnold R. Okuro; Northern California, Raymond C. Martinelli; and Northwest, H. G. Egbert.

Oregon, Earl Marks; Southern California, Peter R. Kyropoulos; Southern New England, Charles Phelps; Syracuse, Prof. O. A. Carnahan; Twin City, Prof. B. J. Robertson; Washington, Geo. A. Barker; Wichita, John I. Clark; and Spokane Group, E. N. Klemgard.

Technical Movies

MOTION pictures continue to put life into Section meetings from coast to coast. Section officers indicate growing usefulness for the list of films available distributed periodically by SAE Sections and Membership Division from New York headquarters. (Headquarters does not distribute films . . . only the list.)

Members can help make that list better by telling SAE Headquarters about industrial and technical films which they think might interest SAE Sections. Along with such suggestions should come, if possible, the film's title, where it can be obtained, running time, whether 16 or 32 mm.

Cal Tech Branch Inspects Wind Tunnel

ON the evening of Aug. 23, 1946 the Caltech Student Chapter of SAE visited the Southern California Cooperative Wind Tunnel run by the California Institute of Technology. The tour was conducted by J. E. Smith, one of the engineers responsible for the design and operation of the tunnel.

Operation of Tunnel

The tunnel is designed to handle air speeds of up to the speed of sound and at pressures varying from four atmospheres to ¼ atmosphere. Power is supplied by one 10,000 hp 3 phase AC electric motor and by a 2,000 hp DC motor so that very close control of air speed can be obtained. The working section of the tunnel is 12 ft wide by 8½ ft high. The weighing system is entirely hydraulic and it can measure forces up to 30,000 lb to an accuracy of one pound and moments up to 10,000 ft lb.

Models to be tested are set up in removable sections of the tunnel throat so that it is possible to be setting up one model while tests are still being run on another model. It is also possible to depressurize the throat section of the tunnel in order to make adjustments on the models without depressurizing the entire tunnel. All data in addition to being shown on gauges is automatically recorded by special IBM recorders and then placed on punch cards which can be fed into other IBM machines to obtain the evaluation of the data without any calculation by hand, thus avoiding the human errors.

The students were not permitted to see any of the models as these are invariably classified material; however, it was stated that some of the models cost as much as $200,000. These models have electric motors to spin the propellers at a rate fixed by variable frequency generators outside the tunnel. These models also have control surfaces which can be actuated from outside the tunnel by either electric or by hydraulic controls.

Committeemen Are Appointed

CHAIRMAN PYKE JOHNSON of the Beecroft Traffic Safety Engineering Lecture Committee has announced the appointment of the committee which will select the annual speaker to receive the award provided in the will of the late David Beecroft.

The group consists of Otto F. Messner, deputy secretary of Revenue, State of Pennsylvania, representing the American Association of Motor Vehicle Administrators; M. J. Hoffman, president of the American Association of State Highway Officials; Roy E. Cole, vice-president of Studebaker Corp., representing the Automobile Manufacturers Association; Major Harvey G. Vallahan, Washington's police superintendent, who represents the International Association of Chiefs of Police, and Thomas H. McDonald, commissioner of the U. S. Public Roads Administration.

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THREE SAE-nominated directors of Cooperative Research Council's Board of Directors have been named to succeed themselves. B. B. Bachman, W. S. James, and C. E. Frudden, whose terms expire Dec. 31, 1946, will begin new two-year terms on the CRC Board on Jan. 1, 1947, following action by SAE Council at its Sept. 12 meeting.

J. M. Crawford, William Littlewood, Arthur Nutt, and J. C. Zeder are the other SAE-nominated members of the CRC Board. Each continues a year.

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E. N. COLE, Cadillac's new chief engineer, has been named to membership on the Passenger Car Activity Committee by SAE Vice-President J. E. Hale.

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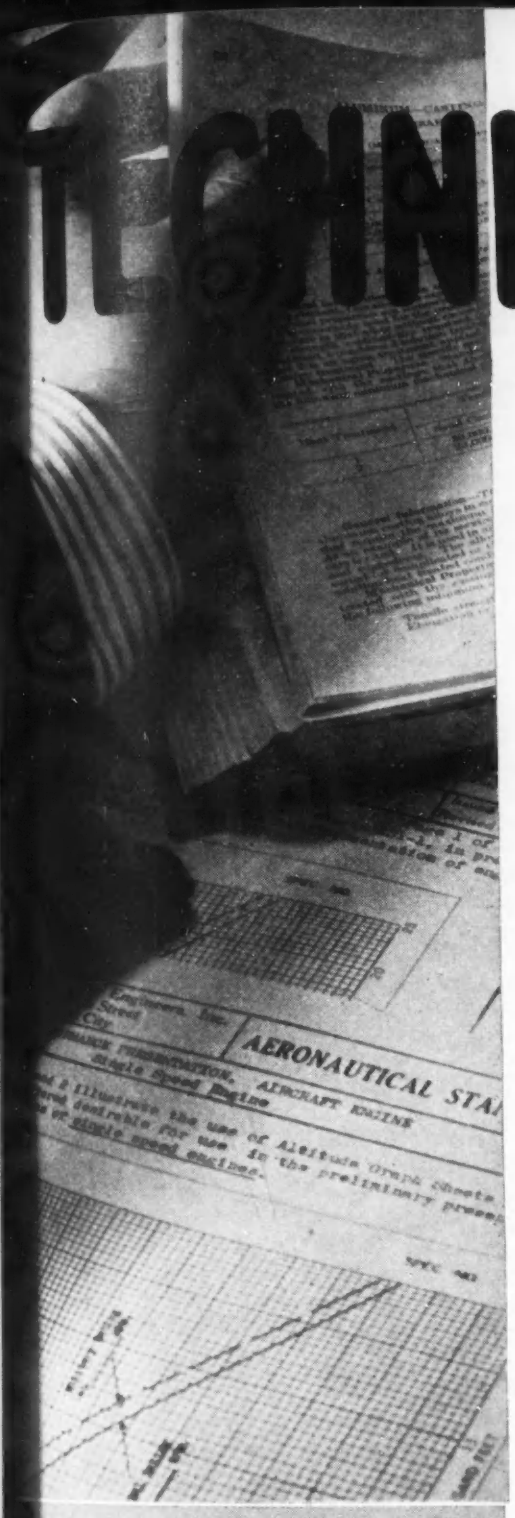
HAROLD R. HARRIS, American Overseas Airlines' general manager, represented SAE officially at a Flying Display and Exhibition held Sept. 12-13 at the Handley Page Aerodrome, Radlett, Hertfordshire, England. The event was held by the Society of British Aircraft Constructors, Ltd.

•

BECAUSE of the untimely death of J. J. Wharam, E. P. Lamb, chief engineer, Truck Division, Chrysler Corp., becomes secretary of the Detroit Section. Mr. Lamb was also appointed chairman of the Section's Meeting Committee, a post which had been held by his predecessor.



TECHNICAL COMMITTEE PROGRESS

SAE's technical program is reflecting the personal aircraft industry's belief that it faces unparalleled growth. Standardization work from which such growth can take off is being sparked by three technical groups started by the SAE Aeronautics Division.

Standards for Private Plane Sparked at SAE

Steering committees have been put in action to guide needed standards development for propellers, for accessories and equipment, and for engines in the personal airplane field. Scope and aggressive plans for the accessories and equipment group were outlined in the August, 1946, SAE Journal. *Here is the story on the newest of the three, the Low Horsepower Engine Committee.*

Standardization of low horsepower aircraft engine parts lending themselves to interchangeability is the goal focused upon by the newly created SAE Committee E-23, Low Horsepower Engines Steering Committee.

The personal aircraft industry is preparing itself for a boom in flying; it is rapidly becoming big business. To compete successfully with other modes of transportation, the personal airplane must be taken out of the luxury class and made available to the greatest possible market. There is only one way to do this, the industry realizes – reduce costs.

Low HP Engine Work Steered By New Group

Since the engine is the most complicated and probably the most costly component that goes to make up the airplane, the Committee feels that much can be achieved in reducing the cost of the airplane by producing a more economical engine. Most direct step to this objective is interchangeability of parts through appropriate standardization.

Low horsepower engine needs and production before the war were relatively limited. With the advent of war, low horsepower engine manufacturing grew and light engines were manufactured in large quantities for military training and liaison planes. But due to the emergency, low horsepower engine manufacturers followed the standards of the large engine manufacturers rather than establishing a program suited to their own specific needs.

Now that the low horsepower engine has come into its own and commands an important niche in the overall postwar aircraft picture, low horsepower engine manufacturers feel they have reached a crucial fork in the road to progress that demands special consideration of problems peculiar to their requirements.

SAE TECHNICAL BOARD

J. M. Crawford, Chairman

B. B. Bachman
D. P. Barnard
R. B. Beisel
R. E. Cole
A. T. Colwell
R. M. Hazen
J. H. Hunt
R. D. Kelly
G. W. Laurie
William Littlewood
Erle Martin
R. H. McCarroll
Arthur Nutt
C. R. Paton
L. S. Pfost
D. G. Roos
C. G. A. Rosen
A. W. Scarratt
Mac Short
T. C. Smith
R. R. Teetor
R. W. Young

J. C. Zeder

Need for adoption and use of pertinent SAE standards by the small engine manufacturers has generated the creation of the new steering committee. Chairman L. A. Majneri, Warner Aircraft Corp., pointed out at the first meeting that light engine manufacturers desire to use automotive equipment; the possibility that present SAE automobile standards might be applied successfully to the light aircraft engine is being investigated.

Whereas Committee E-23 will do most of the standardizing work itself, certain tasks will be delegated to temporary working committees.

Among the projects on which work has already been initiated are the following:

1. Exhaust flanges and gaskets. A proposed Aeronautical Recommended Practice is to be prepared of flanges and gaskets now in use, with automotive practice considered as far as possible;
2. Oil seals for tachometer drives;
3. Ignition shielding;
4. Drives for all electrical accessories. Great need for standardization of accessory drives exists, especially those which are a modification of automobile equipment;
5. Fuel injector units, and
6. Diaphragm type pumps. A new standard is being developed using the automobile type. This standard, it is tentatively planned, will include both the plunger and rod types.

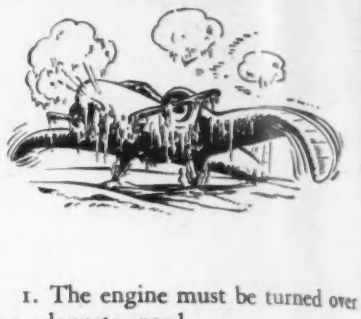
Serving with Chairman Majneri on the Committee are: W. F. Burrows, Air-

Chairman L. A. Majneri

cooled Motors, Inc.; J. W. Kinnucan, Continental Motors Corp.; C. H. Wiegman, Lycoming Division, Aviation Corp., and G. S. Garrard, Jacobs Aircraft Engine Corp.

The Committee was commended by C. E. Mines, Chairman of the Aircraft Engine Subdivision, for the rigorous standardization program it is undertaking.

New Aero Report Consolidates Cold Starting Work Covering 3½ Years Of Intensive Work



PUBLICATION last month of consolidated information gathered through 3½ years of intensive work on cold starting of aircraft engines marks the final action of SAE Aeronautics Division's committee on Cold Starting Requirements for Aircraft Engines, which first swung into action on its vital war project back in the summer of 1942.

During its activities, this group attacked every element of cold starting as related to military operations in cold weather areas, correlated extensive laboratory and field tests, acted as a clearing house for cold starting information during the war period, set forth criteria for each phase of several methods of cold starting, and indicated future lines of research which it is hoped will lead to eventual development of standard procedures.

Net results of the committee's fruitful effort are contained in four documents:

Report on Cold Starting of Aircraft Engines (December, 1942)

Addendum to above report (September, 1945)

Oil Dilution and Cold Starting of Aircraft Engines (November, 1945)

Final Report on Cold Starting of Aircraft Engines (September, 1946)

The committee's accomplishments as revealed in these reports include statements of certain valid procedures for cold starting as well as agreement about desirable features of such procedures where complete criteria are not yet established. Its work concentrated chiefly on six elements of the problem:

1. Cranking rpm
2. Starting power
3. Fuel
4. Ignition
5. Lubrication
6. Clearances.

It was agreed, after discussion and research tests, that the following requirements must be met in any satisfactory procedure for starting engines at sub-zero temperatures:

1. The engine must be turned over at an adequate speed,
2. Sufficient power must be available for two 30 sec. cranking periods,
3. A combustible mixture must be delivered to the cylinders,
4. An adequate spark must be produced,
5. The engine must receive a usable lubricant,
6. The fits and clearances of mating surfaces in the engine must be such that normal functions occur irrespective of the temperature.

In connection with these requirements, a variety of qualifying data were developed.

To satisfy the first condition, for example, it was determined from tests that the engine must be turned over at a speed greater than 20 rpm and that a continuous cranking type of starter gave the most desirable results.

To deliver sufficient power for the two 30 sec cranking periods, it was found, the battery should be kept heated to insure full output if no auxiliary power source is used.

Other tests revealed that a combustible mixture could not consistently be delivered to the cylinders where regular aviation gasoline was used, because such fuel did not vaporize sufficiently during cold weather starting. Inasmuch as highly volatile fuels appeared necessary for both priming and starting, several blends of pentane, butane and propane were tested with varying degrees of success. All these tests pointed to the need for careful metering of special priming fuels to eliminate the hazards of fire and structural failure due to hydraulic lock. It was further observed that the danger of scuffing from washing of the lubricant off the cylinder walls was inherent in the improper use of pentane and butane liquid starting fuels. However, despite pitfalls, special fuels were proved successful in consistent starting down to —65 F provided adequate control was exercised.

To insure production of an adequate spark, the only change to the ignition system found necessary was inclusion of a booster circuit with a voltage greater than the cut-in voltage. Fouled and iced spark plugs were traced to false starting and consequent moisture condensation caused by inadequate fuel delivery, rather than ignition malfunctions. Continued delivery of the proper combustible mixture followed by the uninterrupted firing process does not offer the opportunity for ice to form. Spark plug fouling also resulted from the incorrect use of oil dilution.

The key to satisfactory lubricant performance, the reports indicated, lies in the consideration of two salient properties, viscosity and flowability. The viscosity should be reduced by dilution, for which purpose regular aviation gasoline appears suitable. For suitable flowability, the pour point of the oil should be lower than the starting temperature. The pour point may be lowered by the addition of depressants. However, depressants lose their effectiveness after approximately 24 hours and daily starting or warming to recondition the oil is recommended in the reports.

The virtues of oil dilution, the confreres agreed, may be more than offset by the hazards of unskillful application. Even with the proper amount of dilution, their reports show, engine life will be reduced through ring wear and piston scuffing if the diluent is not driven off quickly enough to obtain sufficient lubrication. Reports show that a rapid warm-up produces less piston scuffing, but the rapidity of the warm-up must be kept consistent with the proper rise in oil pressure. Over dilution carries with it the danger of excessive oil losses through the breather from foaming and spewing.

Consideration of the final requirement on fits and clearances came within the scope of this work when investigations indicated that conventional clearances were reduced to zero and even negative quantities at extreme temperatures. This condition was readily alleviated by resetting clearances to adjust for the anticipated changes.

The reports, in addition to throwing light on the numerous facets of each requisite, give direction to the remaining study and development needed in the achievement of a completely satisfactory cold starting method.

Initial emphasis in post-war work, the reports urge, should be placed on the perfection of a suitable metering system for both liquid and gaseous special starting fuels. Difficulties encountered in using high volatile fuels are directly traceable to improper fuel and air mixtures. None the less needed, it is indicated, is the evolution of a positive means of evaporating the oil diluent to circumvent the possibility of reduced engine life. Realization of these two major objectives will complete the pattern in the fashioning of a successful cold starting procedure.

The success of the Committee on Cold Starting Requirements for Aircraft Engines can be attributed to the cooperative spirit of the members and their respective firms in carrying out numerous assignments instrumental in developing the art to its present advanced stage.

The committee consisted of Chairman G. A. Bleyle, Wright Aeronautical Corp.; H. J. Buttner, Packard Motor Car Co.; F. Dougherty, Allison Division, General Motors Corp.; B. W. Geddes, Standard Oil Development Co.; A. Pomeroy, Ranger Aircraft Engines; H. C. Riggs, Electric Storage Battery Co.; B. J. Ryder, Lycoming Division, Aviation Corp.; T. Spalding, Jack & Heintz, Inc.; and W. H. Sprenkle, Pratt & Whitney Aircraft, Division of United Aircraft Corp.

Of particular assistance to the committee in its work were Past Chairman C. R. Paton, then with Allison Division, General Motors Corp., and Past Member R. E. Johnson of the Wright Aeronautical Corp. In addition, many consultants such as Major J. N. D. Heenen of the British Air Commission from both industry and the Air Technical Service Command's Cold Weather Testing Section contributed materially to the committee's progress.

■ ■

Extent of Decimal Dimensioning Probed by Aero Drafting Group

TO ascertain the degree of utilization of the decimal system of dimensioning drawings, the SAE Aeronautical Drafting Committee has submitted a questionnaire and a listing of recommendations regarding this system of dimensioning to aircraft, accessory, engine, and propeller manufacturers and airline operators.

Present action stems from the Committee's desire to obtain opinions and recommendations of cognizant manufacturers regarding their use of this dimensioning system. Reactions obtained will guide the conferees in determining whether more or less emphasis should be placed on the system in future pursuits. This is in line with the Committee's policy of keeping abreast with up-to-date industry practice.

Long supported by the Committee, the decimal system of dimensioning has again been recommended in the recently published SAE Aeronautical Drafting Manual. This group has not been alone in support of this system as the Working Committee of the Aeronautical Board and the American Standards Association are considering adopting this system in their recommended drafting practices.

Submitted with the questionnaire was the following discussion prepared by the Committee:

"The use of decimals in place of common fractions in dimensioning drawings originated in some industries before World War I. It was recognized in Army Ordnance Drafting Room Manual in 1916 and adopted by the Ford Motor Co. in 1932 to lower costs of manufacturing and has been in general use in the automotive industry as well as the aircraft engine industry before World War II. During World War II it was adopted by many other industries and included in the tentative Drafting Standards promulgated by the American Standards Association and the SAE. Since the time of its use, experience with this system has proved without a doubt that it is far superior to the fractional system.

"The decimal system is not new or strange. Everyone is familiar with its use in the American money system. In this case sums are expressed as units, and decimal parts of those units, for example, $5.20. In the system recommended by this article, it is proposed to write a length dimension similarly, for example 5.20 in.

"The decimal system, as here proposed, does not contemplate a new standard of length. It contemplates exactly the same inch as has been used with the fractional system. Only the method of expressing the dimension is different. It is proposed to write 1.50 rather than 1½, and to use .02 as a unit of the decimal division of the inch in place of 1/64. It

is a substitute for the Metric System which can be put in use without far-reaching changes in tools and gages.

"The reason for this recommendation is simply that decimals are more easily handled when added, subtracted, multiplied, and divided. A further advantage is that scales graduated in decimals are more easily read than those graduated in fractions.

"The simplicity of the system in checking dimensions is shown by the column listed in Table 1. The first column shows the addition of a series of even two-place decimal dimensions which are multiples of .02. The second column shows a series of fractional dimensions which are multiples of 1/64. When the second column is to be added the conversions in the third column are set-up to perform the operation. It is easy to appreciate the great ease in adding the first column of figures.

Table 1 – Comparison of Dimension Checking by Decimal and Fractional Systems

Decimal System	Common Fractional System	Decimal Fraction
.02	1/64	.015625
.06	1/16	.0625
.06	5/64	.078125
.12	1/8	.125
.20	13/64	.203125
.34	11/32	.34375
.38	3/8	.375
Total=1.20		Total=1.203125

"A direct result of the adoption of the decimal system is the simplification of the work of the engineer, draftsman, tool designer, inspector, tool maker and checkers, as shown in Figs. 1, 2, and 3. Let us assume a draftsman laying out a part having a row of holes as shown in Fig. 1.

"In order to be sure that the space marked X contains enough metal, he must refer to a table of decimal equivalents, set them up and perform the operations as follows:

ADD:

7/8 = .875
51/64 = .796875
1 11/32 = 1.34375
1 9/16 = 1.5625
3/4 = .750

5.328125

SUBTRACT:

5 63/64 = 5.984375
5.328125

.656250

.65625 = 21/32 the distance for space X

"If the part, however, is designed with a decimal scale, the layout will look like Fig. 2. To check the distance X is a much simpler matter and entails much less mental effort with a corresponding lesser danger of error.

ADD:
.88
.80
1.34
1.56
.76

5.34

SUBTRACT:
5.98
5.34

.64 is the distance for space X

"Hundreds to thousands of computations such as shown in Fig. 2 are necessary each day in the making of drawings in the average size Engineering Department. All set-ups on machine tools must be made in decimals because the indicating dials are graduated in decimals. Therefore, the tool designer who is designing a piercing die for the part in Fig. 1 must go through the same ordeal of checking the decimal equivalents in order that the tool maker who bores this die may have figures which he may use in stepping off these holes with the lead screws and dials on the boring mill. Notice how much less the chance of error would be if he were stepping off .88, .80, 1.34, .76 and 1.56 in place of .875, .796875, 1.34375, .750 and 1.5625. The inspector checking the part from this die against the blue print must go through the same ordeal as the draftsman and the checker did as in Fig. 1.

"Common fractions were a very practical medium of measurement in the day of the common calipers, but now that the lead screw, micrometer, vernier height gage, and vernier calipers are our tools of measurement, and these devices read entirely in decimals, it is much more practical to also have drawing dimensions shown in the decimal system.

"The comparison in simplicity between the decimal system and the fractional system becomes apparent when it is required to determine dimensions through the use of trigonometric functions where sines, cosines, and tangents of angles must be multiplied or divided by dimensions. Fig. 3 shows the layout of a part which must have dimensions X and Y calculated in order that the shop may produce the part. The computations in the fractional systems are as follows:

X = 1 7/32 times Cosine 32°
1 7/32 = 1.21875
Cosine 32° = .84805

609375
9750000
487500
975000

1.0335609375

Y = 1 7/32 times Sine 32°
1 7/32 = 1.21875
Sine 32° = .52992

243750
1096875
1096875
243750
609375

.6458400000

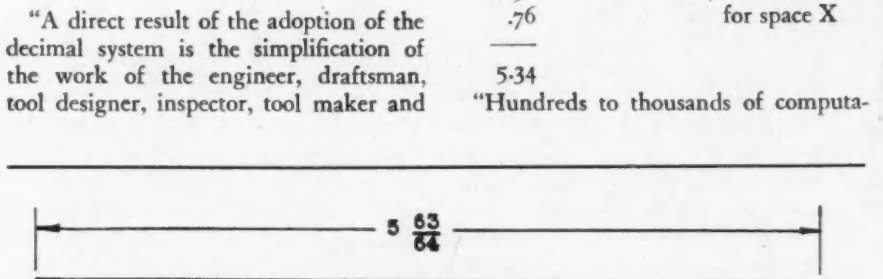
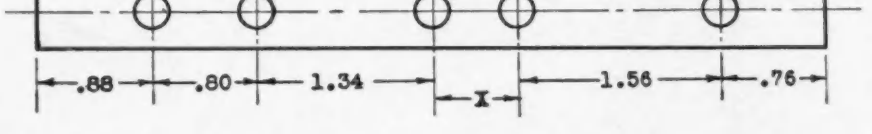


Fig. 1 – Fractional dimensioning of drawing of a part

Fig. 2 – Decimal dimensioning of part shown in Fig. 1



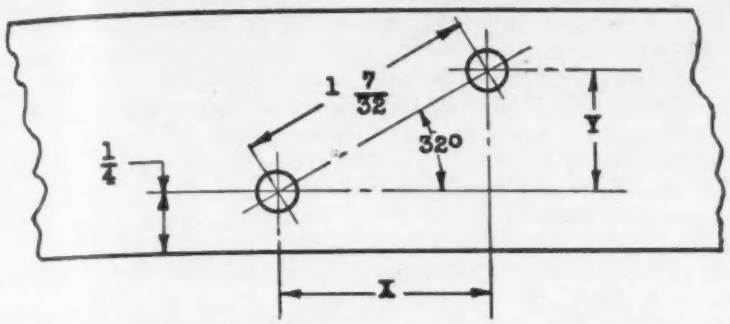


Fig. 3 – Mathematics for determining unknowns X and Y is much simpler by the decimal dimensioning system than it is by the fractional system

"Note how much simpler this is when 1.22 is used in place of 1 7/32.

Cosine 32° = .84805
1.22

169610
169610
84805

1.0346210

Sine 32° = .52992
1.22

105984
105984
52992

.6465024

"Aside from the advantage of easy computation and simpler design layout, a significant advantage also exists when the decimal scale is used for layout in the shop. This advantage becomes apparent when Fig. 4 is compared with Fig. 5. Note the improvement in the legibility of the graduations of the decimal scale when compared with the fractional scale.

Easier on Eyes

"The eye strain is immediately reduced and errors are lessened due to this improved legibility. This is due to the increase in the distance between the 1/64 (.015) graduations on the fractional scale and the 1/50th (.020) graduations on the decimal scale. The distance between graduations on the decimal scale is 30% greater than on the fractional scale. It is this increase in distance which reduces eye strain.

"In connection with the use of the decimal system of dimensioning, it is necessary to carry on the drawing exact decimal equivalents of fractionally dimensioned standard items; for example, thread sizes, drills, reamers, rod and bar materials. This is necessary for the time until the suppliers of these items can convert to the decimal system.

"In order to pave the way for the transition from fractions to decimals, it may be expedient to start with three-place decimals as an approach to the ultimate two-place decimal system. In this case, all common fractions would be retained but written as three-place decimals. For example, 1/64 and 7/32 would be written as .016 and .219. Such a method would serve where an existing design is slightly changed and a new part number allocated; where the utilization of existing tools or gages is desirable; where it is necessary to satisfy conformance requirements of old specifications; or where drawings of outside manufacturers are converted from fractions to decimals.

Transition To Be Gradual

"The two-place decimal system with dimensions written as three-place decimals would then be reserved for new design work. For example, .02 and .22 would be written as .020 and .220. By progressive elimination this method would permit a gradual replacement of the 1/64th unit by the 1/50th unit as the division of the inch. The third place zero from dimensions like .020 and .220 could then be dropped and the full benefits of the system would eventually be obtained.

"A very interesting side light in connection with the use of the decimal system has been the ease of instructing female workers in industrial plants using this system during World War II. Many schools and colleges were called upon to train women for engineering and drafting or inspection work and many educators discovered the ease with which these trainees could learn the decimal system of measurement. Whereas, it was very difficult to train these women in the common fractional system. It was also noticed during World War II that male workers from industries using a system of measurement other than the fractional system or workers who had never seen a common fractional scale could be taught the decimal system in less time than it would take to teach the common fractional system.

"The adoption of decimal dimensioning by many in the auto and aircraft industries is evidence that it is superior to common fractional dimensioning. Any industry whose engineering and shop labor costs must be held to a minimum will better its chances to survive competition by the adoption of the decimal system of dimensioning."

Answers to the questionnaire and all comments received will be summarized by committee member P. J. Hayes, Jr., American Airlines, Inc., and submitted to the Committee for further discussion in determining future handling of decimal dimensioning in the manual.

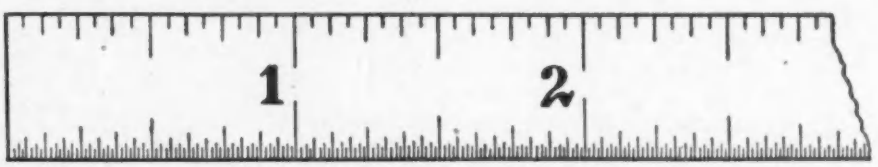
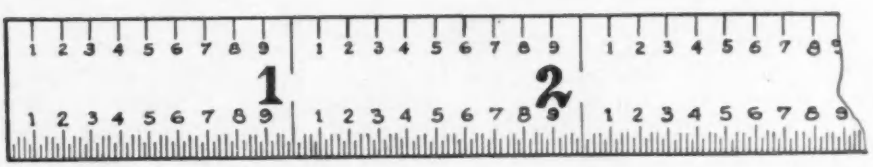


Fig. 4 – Common fractional scale

Fig. 5 – Decimal scale is easier on the eyes than the fractional scale in Fig. 4



Battery Specifications Undergoing Revisions

REVISIONS and additions to the SAE Handbook section on storage batteries are now being studied by the Storage Battery Subcommittee of the SAE Electrical Equipment Committee.

First phase of this undertaking is the revision of the Battery Classification, Ratings, and Dimensions Table. Notable among the changes proposed by the Subcommittee and to be submitted for approval to the parent committee before final submission to the Technical Board is the reclassification of battery types. It is proposed that the 27 classifications now listed be reduced to 13.

Another tentative change is the method of specifying various rating values. An acceptable range of values is to be indicated instead of just one specific value. This method of specifying tolerance makes for greater utility of the tables.

Additions to the table, which comprise the second phase of the Subcommittee's operations, consist of determining data on heavy duty batteries heretofore omitted in part from the table. Complete information is now being gathered on the following:

1. Suggested minimum values in minutes and 5-sec voltage at 300 amp discharge rate at 0 F for automotive batteries. Fully charged batteries will be subjected to the following tests:
   a. Discharge at 25 amp to terminal voltage equivalent to 1.75 v per cell at 80 F. New batteries shall meet this rating at the first discharge.
   b. Recharge and discharge at 300 amp at 0 F to terminal voltage equivalent to 1.0 v per cell. The 5-sec voltage is to be taken during this test. The battery is to meet the rating on the first discharge after the initial 25-amp discharge test. The fully charged battery must have been exposed to 0 F ambient temperature a minimum of 18 hr prior to this discharge.
   c. Recharge and discharge at 20-hr rate at 80 F. Three successive discharges at this rate shall be permitted (following the 0 F) for the battery to meet its rating.
2. Data on heavy duty motor coach and diesel batteries, sizes 4D and 8D, for the purpose of establishing cold ratings.

A battery is considered fully charged when the specific gravity and voltage of all cells fail to rise during three successive readings taken at 1 hr intervals while the battery is being charged at the rate of 1 amp per positive plate cell. Gravity readings must be corrected to a standard temperature of 80 F.

Chairman F. A. Franklin, GMC Truck & Coach Division, has instructed the subcommittee members to collect the above data for consideration at the next meeting to be held in Detroit early this month.

SAE activity in the storage battery field stems back to 1914, at which time the first SAE storage battery specifications were adopted. These original specifications included classifications, dimensions, and ratings. Next major step in the direction of battery standardization was made by the SAE in January, 1934; standard test procedures were adopted to check battery capacity against designated ratings.

But further standardization appeared necessary. To the SAE Electrical Equipment Division fell the task of establishing standard life tests for batteries. These tests appeared for the first time in the 1936 SAE Handbook.

Storage battery specifications and standards have been useful to producers and users through the years. For example, ever since the Federal Specifications Board has been charged with the responsibility of preparing purchasing specifications covering storage batteries used by Government services, SAE specifications have been incorporated by the FSB in their specifications. Close liaison with the FSB has been maintained by the Electrical Equipment Committee on all matters pertaining to battery specifications.

On the producer side of the fence, the Committee has been working very closely with the American Association of Battery Manufacturers. This group includes builders of batteries for both original equipment and replacement. The AABM has endorsed SAE specifications for its use.

Present Plans

Present plans of the Storage Battery Subcommittee are to revise SAE battery specifications in order to bring them up-to-date and to make them apply specifically to both original as well as replacement equipment. The AABM has been invited to participate in this work.

Serving with Chairman Franklin on the Subcommittee are: R. A. Daily, Delco-Remy Division, GMC; H. C. Doane, Buick Motor Co.; L. S. Gerber, Army Ordnance; H. C. Riggs, Electric Storage Battery Co.; L. E. Wells, Willard Storage Battery Co.; H. D. Wilson, Electric Auto-Lite Co.; E. F. Webb, Chrysler Corp., and A. Toelle, Ford Motor Co.

Plan Plane Accessories For Speedier Removal

SIMPLIFIED aircraft maintenance and greater accessibility is the prime objective of Committee E-24, Accessory Drives and Flanges, in developing quick attach-detach accessories.

Accessories are presently being attached to mounting pads by means of 4 to 6 studs or bolts. Not only is the time required for removing or replacing an accessory excessive, but the nuts are often located in hard-to-get-to places. Facile maintenance demands rapid removal and installation. With this criterion in mind, the Committee is exploring quick attach-detach devices which lend themselves to aircraft accessories.

One type of device was displayed at the last committee meeting by C. E. Metsger, Bendix Aviation Corp. This design incorporated flanges on the accessory and engine connections held together by a double hinged clamp. This type presupposes the use of round flanges. The clamp is grooved to clasp tightly the chamfered accessory and engine flanges and is held in place by one bolt.

Several suggestions to improve this design were made at the meeting. One recommendation was to install the bolt as nearly tangent to the accessory flange as possible to minimize the bending effect in the clamp previously produced. A second suggestion was to provide the clamp with an effective groove diameter slightly larger than that of the accessory flange. This would enable the clamp, when installed, to have a relatively even circumferential tension.

These and other refinements will be incorporated in the design and distributed to the Committee for further study.

Drawings of another device, developed by Leece-Neville Co., were also shown to the Committee. This device includes 20 interlocking jaws and a one-piece external clamp fitting over the flanges, similar to the Bendix design. Whereas the torque in the Bendix device is carried by

dowel pins, this device depends largely on the clamp itself to carry the torque. Both this proposal and a third one being developed by Jack & Heintz are also to be submitted to the Committee.

After reviewing and testing these and other devices which may be proposed, the Committee plans to prepare a recommended practice on quick attach-detach devices. It was generally agreed that threaded devices would not be considered in view of previous unsatisfactory experience with fine threads on large diameters.

Another important item on the Committee's agenda is the development of a series of accessory pads – square shape for smaller sizes and round shape for larger sizes. Work on round pads has been tentatively deferred as development of attach-detach devices may preclude the need for this program. Development of square mounting pads is being continued as it is felt that the need for uniformity in the smaller sizes still exists.

Membership of Committee E-24, Accessory Drives and Flanges, is made up of engineers from the engine and accessory field and includes N. F. Rooke, Pratt & Whitney Aircraft, chairman; C. E. Hockert, Allison Division, GMC; J. A. Lauck, Pesco Products Co.; C. E. Metsger, Bendix Aviation Corp.; J. L. Nagely, Packard Motor Car Co.; J. Robbins, Aircooled Motors Corp.; H. Schroeder, Jack & Heintz Precision Industries, Inc., and T. R. Thoren, Thompson Products, Inc.

McCormick Heads TTC, New Project Launched

ELMER McCORMICK, chief engineer, John Deere Tractor Co., was elected chairman of the SAE Tractor Technical Committee at the last regular meeting of the TTC in the Palmer House, Chicago.

The new chairman succeeds A. W. Lavers, chief engineer, Agricultural Equipment Division, Graham-Paige Motors Corp., who served as head of the TTC and its predecessor, the Tractor War Emergency Committee, from the latter's inception in 1942. Mr. Lavers continues as a member of the TTC.

C. A. Hubert, manager of engineering, Farm Tractor Division, International Harvester Co., was elected vice-chairman.

Other members of the TTC are J. M. Davies, Caterpillar Tractor Co.; L. A. Gilmer, Oliver Corp.; D. C. Heitshu, Harry Ferguson, Inc.; L. S. Pfost, Massey-Harris Co.; O. R. Schoenrock, J. I. Case Co.; W. F. Strehlow, Allis-Chalmers Mfg. Corp., and Ben G. Van Zee, Minneapolis-Moline Power Implement Co.

Tire and rim engineers from the United States and Canada attend TTC meetings as consultants.

Working under an assignment from the SAE Technical Board with C. G. A. Rosen, Board member and Director of Research of Caterpillar Tractor Co., as project sponsor, the Tractor Technical Committee is undertaking the development of a specification for spark and flame arresters on vehicles operating in

Elmer McCormick

environments where fire hazard is serious. The specification will cover exhaust and manifold systems.

Tractor manufacturers as well as airlines are reported to be considerably concerned about this subject of fire hazard. Interest in the development of a flame arrester specification has been expressed by Lyle F. Watts, Chief, U. S. Forest Service, and W. C. Spouse, mechanical superintendent, British Columbia Forest Service. Mr. Watts has offered to provide the new Flame Arrester Committee with all possible technical assistance.

Experimental Program Begun

Tractor engineers in cooperation with tire and rim technicians have begun an experimental program. They hope to determine the advantages of the new wider based tractor rims, with tires to match, designed to absorb the excessive front end loads to which tractors are subjected in ordinary farm usage.

The tire and rim simplification program was started by the Tractor War Emergency Committee and is being continued by the TTC with the endorsement and cooperation of tractor engineers and tire and rim technicians alike. It has reached the point where a much simplified basic list of tire and rim sizes appears to satisfy the great majority of the needs for future tractor design. The simplification program has recently been expanded to include wheel mountings. This program is confined solely to future designs. No thought has been given to changes in present tire, rim or wheel requirements.

Buttress Thread Group Evolving Aero Standards

AGREEMENT has been reached by SAE Committee P-10, Propeller Buttress Threads, to recommend revision of the ASA Proposed International Buttress Thread Standard and to develop a new Aeronautical Standard on a 15 deg buttress thread.

Committee action on development of buttress thread standards had been deferred pending review of the ASA proposed American Standard B1.10/64 – assigned to the American Standards Association by the International Screw Thread Conference at Ottawa in September, 1945. Chairman M. E. Cushman, Curtiss-Wright Corp., Propeller Division, reports for the Committee that the proposed ASA standard does not meet American aircraft propeller manufacturers' requirements, although certain phases are applicable to propeller usage.

In view of the propeller industry's wide usage of buttress threads, the Committee feels justified in suggesting changes to the ASA proposal. It will recommend to the ASA that the present 7 deg face angle be maintained, but that the proposed standard include a greater number of sizes and that unequal truncations and root radii be shown as optional.

Propeller manufacturers are eager for buttress thread standardization because characteristics of this thread form are well-suited to the high propeller-hub stresses in one direction – along the thread axis. Making the thrust face of the thread nearly normal to the thread axis reduces the resultant radial thrust component to a minimum and produces solid mating between the mating threads.

Serving on the Committee with Chairman Cushman are R. L. Camping, Aeroproducts Division, GMC; W. L. Greene, Engineering & Research Corp., and F. E. Richardson, Army Air Forces.

Fresh Start for Section Reports

The new SAE Section year is swinging into action as this issue goes to press.

Three Sections, Oregon, Southern California and Northern California, heard Air Commodore Frank J. Whittle give his paper on the advent of the aircraft gas turbine, first presented at Metropolitan Section's July 15 meeting. (September *SAE Journal*, p. 26.) Cleveland Section heard Cearcy D. Miller, NACA, report on new photographic methods of knock testing (see p. 34).

Next month field editors of many Sections will have sent in reports. *Every field edititor's report which reaches New York on or before Oct. 15 will show up in these Section Meetings pages in November.*

Sees Bright Future for Jet Powerplant

by C. K. TAYLOR, Field Editor

INDIANA Section, Sept. 12 – Importance of turbo and prop jet engines was emphasized by T. S. McCrea, assistant chief engineer, Allison Division, General Motors Corp., at the first technical meeting of the Section year.

Descriptions of several designs of these new powerplants were given by the author, who illustrated his paper. The speaker has been directly associated with the Allison jet manufacturing program, and during the past two years the division has manufactured more jet equipment than any other concern in the world.

Mr. McCrea predicted a bright future for jet powerplants both for the military defense of the nation and for air transportation.

A former resident of Japan, the author was called on by Gen. James Doolittle for advice regarding engines prior to the Tokyo raid planned and commanded by the general. Subsequently he was in close contact with the Army and Navy in correlating specifications of jet engines.

Oil Meeting Raises Vigorous Discussion

by C. H. MORRISON, Field Editor

HAWAII Section, Aug. 19 – Oil men and truck builders argued at length over suggestions for engine design changes suggested by Union Oil Co.'s Dr. E. B. Lien in a paper read at this meeting by Leo D. Lavering, of Union's Honolulu branch. J. G. Holstrom and R. C. Norrie, Kenworth Motor Truck Corp. executives, were visitors from the mainland who were welcomed by the 25 members and 12 guests in attendance. Mr. Holstrom, Kenworth's vp and general manager (a past-chairman of SAE's Northwest Section), told the Hawaii group how truck makers are lightening vehicles by using aluminum whenever possible – and torsion bar suspensions instead of springs. Mr. Norrie, Kenworth's chief engineer, gave an advance resume of the papers presented at the SAE National T & M Meeting in Seattle Aug. 22-24, a meeting of which he was program chairman.

Hawaii Section Vice-Chairman John G. Brittain presided at the meeting, Chairman Arthur F. Wallace being absent on a visit to the mainland. Roy A. Craw, Sr., Tidewater Oil Co., came closer than anyone else to estimating the viscosity in seconds of oil in a sealed glass bottle which was passed among those in attendance. He came within 19 sec.

Dr. Lien's paper, which featured the meeting, predicted widespread application to civilian equipment of wartime gained knowledge about all-purpose compounded oils. He reviewed some of the problems faced and solved by the oil industry during its recent experimental work, and suggested some improvements in engine design to help alleviate a few difficulties.

Special problem in recent years has been generated by rapid increases in engine power output without corresponding increases in size. Engine temperatures have risen because quantity and rate of circulation of oil have remained unchanged. Loads on oils also have been increased by more severe operating conditions.

Thus the early experimental work with low viscosity index naphthenic oils for sludge prevention; subsequent use of oil-soluble soaps to aid peptization of grease and dirt without excessive wear rate; development of an additive oil harmless to cadmium-silver and copper-lead bearings used to cope with increased loads and engine speeds; and finally marketing of all-purpose lubricants of both low and high viscosity indexes.

Recommended engine design changes included:

1. Oil cooled pistons similar to those now in use in aviation and some diesel engines; these would reduce engine heating in heavy duty service.

2. Tapered ring in a tapered land to increase cleaning action and reduce the

possibility of trapping fuel decomposition products.

3. Changes in composition of connecting rod bearings to obtain metals that will better resist both hot and cold corrosion, have longer life.

4. Improvements in piston head design.

5. Increased crankcase capacity for the average engine; removal of all unnecessary connections and tubing; design and casting of the unit as an integral part of the engine rather than an accessory.

CONWAY

. . . . of Metropolitan

It's mighty difficult, these days, to have to go easy on sales effort when for a good many years one has spent every working moment (and others too) in inducing customers to sign on the dotted line. Such is the predicament of William E. (Bill) Conway, Chairman of the Metropolitan Section of SAE. Bill, as assistant director, National Accounts Division of Studebaker Corp., and his men, cover the eastern seaboard, calling on fleet owners, both actual and prospective, of the cars and trucks manufactured by his company. He has been doing this for 16 years.

He has been a member of SAE since 1937, and has always evinced great interest in Society and Section activities. When presiding at Section and Governing Board meetings, Bill Conway is direct and efficient. In fact, some at first mark him down as being on the brusque side – however, after a few contacts one can see that he merely favors, from experience, the straightforward approach as being most productive of results in the shortest time. Associates who work

with him under all sorts of conditions say that he is a good man to have around.

He is usually found on the end of a good cigar, apparently his favorite form of tobacco. As to a hobby, his friends say it is golf. Also, they will add, he is pretty good at it. In secret, they'll confide that while his average is good, he can at times be disgustingly erratic.

Metropolitan Section is confident that it has a first-class chairman for the season of 1946-1947. – By Charles F. Foell, Field Editor.

COX

. . . . of Cleveland

John R. Cox, Cleveland Section Chairman, is a human dynamic personality with a friendly disposition and a zest for living. His ability to get along with others, coupled with a deep insight into manufacturing problems and processes and an unusual capacity for coordinating production activities, lies behind his chain of accomplishments to date.

Born in Cleveland, Aug. 1, 1897, he secured his formal education in that city and entered the industrial field at an

early age following apprentice training with the Warner & Swasey Co. He served as superintendent of the Kunkle Valve Co. of Fort Wayne, Ind., from 1919 to 1920, and was general foreman of the Foster Machine Co. of Elkhart, Ind., the succeeding year.

Cox's first business venture came in 1921 when he organized the Cleveland Piston Mfg. Co. and rapidly built it up to a nationally known production enterprise, producing "Cleveland" cast iron pistons. Following a steady expansion, the business was sold to Thompson Products, Inc., in 1929, and Cox continued to manage it. In 1933 he became director of manufacturing for all Thompson Products plants and continued in that capacity until 1939 when he resigned to become vice-president and general manager of the Weatherhead Co. Five years later he again went back into business for himself by buying and expanding the Balas Collet Mfg. Co. which today is a thriving enterprise.

Cox was elected president of the National Screw Machine Products Association in 1945. He has been active in SAE and served various offices and committees before being elected chairman in May, 1946.

His hobbies are yachting, flying, and fishing. The proud possessor of a 53-foot cabin cruiser, he has been in the forefront of Cleveland yachting circles. He lives with his wife and 10-year-old son at Clifton Park Lagoon in Lakewood. – by Wilson B. Fiske, Field Editor

MOXEY

. . . . of Philadelphia

John G. Moxey, Jr., Philadelphia Section Chairman, is one of the youngest of this year's Section leaders. Into the 11 years since graduation from Swarthmore College, he has quietly packed a wealth of technical achievement and administrative aptitude. He took a straight 10-mile hike from his Swarthmore text books to the Sun Oil Co.'s automotive laboratory at Marcus Hook, Pa. – and has been there ever since. Now he is assistant chief engineer of the Automotive Section of Sun's Development Division. (His boss, Ludlow Clayden, has been a member of SAE for 36 years.)

Since 1939, Moxey has been increasingly active in projects of the Cooperative Fuel Research and its successor, the Coordinating Research Council. During the war, he headed the Operation and Maintenance Group of CRC's Aviation Fuels Division, in addition to taking part in other phases of CRC work.

Always alertly interested, but never ruffled, he moves smoothly in group activities, combining clarity about objectives with softness of manner. His

personal interests center about his wife, his 8-year-old daughter, 4-year-old son – and golf. Golf gets less attention than the family, so no outstanding scores are reported.

He joined SAE in 1937 and has been working for the Philadelphia Section ever since. – by Robert W. Donahue, Field Editor

These three biographies inaugurate a new SAE Journal *feature. Written by Section field editors, it will introduce new Section Chairmen each month. Watch future issues for a story about your Chairman.*

About SAE Members

Ralph E. Flanders

Tantamount to election, RALPH E. FLANDERS, president of Jones & Lamson Machine Co., Springfield, has been nominated by the Republicans of Vermont for senator. He was active in developing the SAE screw thread standards, and headed the National Screw Thread Committee, established by an act of Congress some years ago. At the time of his nomination he was president of the Federal Reserve Bank of Boston. Starting his career as a machine apprentice just before the turn of the century, Mr. Flanders later worked as design engineer for several companies and from 1905 to 1910 was associate editor of *Machinery*. After two years with Fellows Gear Shaper Co., he joined Jones & Lamson as manager, and was elected president of the company in 1933. He was elected president of the ASME in 1934, ten years after he served a term as president of the National Machine Tool Builders Association. Author of numerous technical papers, he has been active in industrial, social, and Government advisory groups and served as an administrator of OPM during the war.

WAYNE H. BROWN has accepted a position with Douglas Aircraft Co., El Segundo, Calif.

DANFORTH M. GOOGINS has been transferred to the South Portland, Maine, office of Socony-Vacuum Oil Co., Inc. He had been in the company's Worcester, Mass., office.

Chairman of the SAE Southern New England Section, **KENNETH F. THOMAS,** has taken a position as manufacturers' representative, Bearings and Alloy Precision Products, West Hartford, Conn. Mr. Thomas had been district field engineer, SKF Industries, Inc., Hartford, Conn.

Formerly an enrolled student at Yale University, New Haven, Conn., **JOHN P. COONEY** is now emyloyed by The B. F. Goodrich Co., Akron, Ohio.

N. KIRKHAM, previously employed by Caltex Oil, Ltd., Napier, New Zealand, is proprietor of Howick Bus Co., Howick, Auckland, New Zealand.

Upon discharge from the U. S. Navy, **ROMAN B. CUZACK** took a position as mechanical designer, Ford Motor Co., Engineering Laboratory, Dearborn, Mich.

Formerly an ensign, U. S. Navy **HERBERT PHILLIPS** is currently working as a research engineer, Philco Corp., Philadelphia.

A graduate of Purdue University and a SAE enrolled student, **HARRY K. SCHALL** is now working for McDonnell Aircraft Corp., St. Louis, Mo.

Formerly affiliated with DeHavilland Aircraft Co. of New Zealand, Ltd., Wellington, New Zealand, **J. J. A. O'HARA** is now service engineer, Public Works Department, Auckland, New Zealand.

Formerly district sales engineer, Jones and Laughlin Supply Co., Charles City, Iowa, **HAROLD A. COOK** is currently engaged as design engineer, Funk Aircraft Co., Coffeyville, Kan.

Formerly an enrolled student at Purdue University, **EDWARD M. DISS** has currently taken a position as development engineer, Prest-O-Lite Co., Speedway City, Ind.

WOLFE

Pan American World Airways has appointed THOMAS WOLFE vice-president in charge of its Pacific-Alaska Division, with headquarters in San Francisco. Mr. Wolfe has been in air transportation for more than 22 years.

ROBSON

Recently discharged from the Army as a lieutenant-colonel JAMES J. ROBSON rejoined Firestone Tire and Rubber Co. of California, West Coast Division, Manufacturers' Sales Department.

LeGROS

Prior to his return to Scripps Motor Co., LAWRENCE S. LeGROS had been associated with the General Motors Corp. in various executive engineering capacities.

W. H. CARHART is a sales engineer for Western Gear Works, Lynwood, Calif. He had been with the west coast plant at Thompson Products, Inc.

WHITE

Until recently director of engine research, Oldsmobile Division, General Motors Corp., Lansing, Mich., HAROLD S. WHITE is now head of engine research, Ford Motor Co., Dearborn, Mich.

EAGER

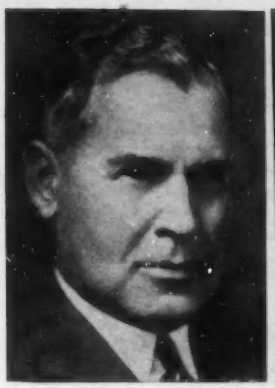
For the past six years with Burlington Steel Co., Ltd., Hamilton, Ont., NORMAN A. EAGER has been appointed general manager. Mr. Eager was a state highway engineer before entering the public utility field.

KELLER

HARRY L. KELLER has recently been called to Ohio Crankshaft Co., Cleveland, as manager of the Commercial Engineering Department established by the TOCCO Induction Heating Division of the company.

General Motors Division Managers Appointed

THOMAS P. ARCHER, vice-president, who has been general manager of the Fisher Body Division, will be group executive in charge of a new group of Divisions consisting of the Fisher Body Division, including Ternstedt, and the Buick-Olds-Pontiac Assembly Division. L. C. GOAD, vice-president, who has been in charge of the Buick-Olds-Pontiac Assembly Division and Dayton and Household Appliance Divisions, takes over Mr. Archer's former task as general manager of the Fisher Body Division, including Ternstedt. B. D. KUNKLE, vice-president, heads the Dayton and Household Appliance Divisions.



T. P. ARCHER

L. C. GOAD

B. D. KUNKLE

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BAXLEY

Vice-president and technical director of Intava Inc., C. H. BAXLEY, is making an extended trip to South and Central America, where he will visit Trinidad, Brazil, Argentina, Chile, Peru and Panama.

ROBBINS

Previously aeronautical consultant, HUGH C. ROBBINS has been appointed manager of Materials Department, Fairchild Aircraft Division, Hagerstown, Md.

MARTIN

ERLE MARTIN has been appointed acting general manager, Hamilton Standard Propellers Division, United Aircraft Corp., East Hartford, in addition to his present position as engineering manager of the Division.

APPEL

As announced in the July SAE Journal, WALTER D. APPEL is now assistant to vice-president of engineering on product development, Willys-Overland Motors, Inc., Toledo.

Previously a lieutenant (j.g.) U. S. Navy, **E. F. DeTIERE, JR.,** has now become affiliated with American Bosch Corp., Springfield, Mass.

PERRY A. CLARK has transferred from the Kansas City, Mo., office of Transcontinental and Western Air, Inc., to their Newcastle, Del., location at Newcastle County Airport.

ROBERT W. TEEL has resigned his position as process engineer, Boeing Aircraft Co., Seattle, Wash., to return to school at the University of Oklahoma, Norman, Okla.

GEORGE LOGAN is serving as foreman, British Overseas Airways Corp., Victoria, London, England. He was engineering officer for the same company at Baltimore, Md.

COLIN J. McFARLANE has recently returned to Calgary, Alberta, Canada, from a long visit to the west coast where he was recuperating from a serious illness.

Prior to his employment by Scintilla Magneto Division of Bendix Aviation Corp., Sidney, N. Y., **OSCAR SOKOL, JR.,** was a designer for Saginaw Steering Gear Division, General Motors Corp., Saginaw, Mich.

Formerly with Republic Aviation Co., New York, **DAVID H. MOORE, JR.,** is now an engineering designer for Consolidated Vultee Aircraft Corp., San Diego, Calif.

RUDOLPH SCHNEIDER has retired from active service as chief engineer, design, Busch-Sulzer Bros. Diesel Engine Co., St. Louis, Mo. However, Mr. Schneider's services as a consultant have been retained by the company.

RALPH W. LOHMAN, electrical engineer, has taken a position with Quaker Shipyard & Machine Co., Camden, N. J.

WALTER E. WILSON has returned to Bower Roller Bearing Co., Detroit, after serving 38 months in the U. S. Navy.

Formerly assistant plant manager, Wright Aeronautical Corp., Wyoming, Ohio, **RUSSELL T. HOWE** is now plant engineer, Drackett Chemical Co., Cincinnati, Ohio. Mr. Howe was chairman of the Cincinnati Section last year and is serving as Student Committee Chairman for the current Section year.

CHARLES B. WONDERS is currently serving in the Corps of Engineers, United States Army, Fort Belvoir, Va.

GEORGE KRIEGER, Ethyl Corp., has completed formation of an Agricultural Development Committee of the American Petroleum Institute which aims at linking more closely the agricultural and petroleum industries. Named chairman of the group at its formation last April, Mr. Krieger is devoting much time to stimulation of the Committee's program which includes encouragement of research looking toward more efficient farm practices, gathering and distribution of agricultural-petroleum information, cooperation with professional societies and other organizations, and exploring the market and source relationships between the two industries. . . . Other SAE members serving on this Committee are: K. G. MacKenzie and C. F. Ramey.

Mr. Krieger also spoke before the Agricultural Insecticide and Fungicide Association at their annual meeting, Sept. 3-5, in Spring Lake, N. J.

ARTHUR F. WALLACE, Chairman of SAE Hawaii Section, sailed for home on Sept. 27 after a combined busines and pleasure trip to the Mainland which began Aug. 12. Traveling clear to the east coast and back, Mr. Wallace visited SAE Headquarters in New York during his tour. He is factory superintendent of the Waialua Agricultural Co., Ltd., Waialua, Oahu, T. H.

Formerly material engineer, Lockheed Aircraft Corp., Burbank, Calif., **JAMES L. KINSEL** has taken a similar position at Menasco Manufacturing Co., Material Control Section, Burbank.

LEONARD VELANDER, JR., previously a lieutenant (j.g.) U. S. Navy, is now associated with Walker Manufacturing Co., Racine, Wis.

Prior to his affiliation with the Ordnance Division, Bell Aircraft Corp., Burlington, Vt., **EDWARD H. JACOBS** was employed by Bendix Aviation Corp., Marine Division, Norwood, Mass.

JOSEPH A. BROSSEAU is now employed by American Overseas Airlines, Westover Field Project, Chicopee, Mass. He had been an engine test operator, Pratt & Whitney Aircraft Division, United Aircraft Corp., East Hartford, Conn.

OTTO LESSING, formerly petroleum engineer, Foreign Marketing, Standard Oil Co. of N. J., New York, N. Y., is now with Standard Mineraloelprodukte A. G., Zurich, Switzerland.

SAE Members in the News

Mystery Bullet Missed . . .

Disclosure of wartime Pentagon Building mystery during the summer of 1942 was recently made by the War Department. MAJOR-GEN. G. M. BARNES, then chief of the Ordnance Department Technical Division, happened to turn away from the path of a bullet which was fired through a glass door. The retired general is now technical assistant to EDWARD G. BUDD, president of Budd Co., Philadelphia.

Awarded Bronze Star . . .

LT.-COL. WILLIAM C. WINE (at the right), Ordnance Department, U. S. Army, is shown receiving the Bronze Star Medal from Lt.-Gen. John E. Hull, Commanding General, for meritorious achievement in connection with military operations against the enemy in the Hawaiian Islands. Colonel Wine is currently Commandant, C.P.B.C. Motor School in the Middle Pacific area.

Inspects Automobilia . . .

Chairman JOHN R. COX (extreme left) of the SAE Cleveland Section is examining volumes of the Peerless Collection of Early Automotive Literature with Clarence S. Metcalf, director of the Cleveland Public Library, and James A. Bohannon, the last president of Peerless Motor Car Corp., the donor of the collection to the Library. The latter is now president of the Brewing Corp. of America.

Gets Oak Leaf Cluster . . .

COL. JOSEPH M. COLBY (at the right) was presented with the Oak Leaf Cluster to the Legion of Merit by his Commanding Officer, Colonel Burton O. Lewis, at the offices of the Detroit Arsenal, Centre Line, Mich. Colonel Colby received this award for engineering work on an Army heavy tank, T32, and for meritorious service as chief of key divisions of the Detroit Arsenal during World War II.

70 Years Young . . .

CHARLES F. KETTERING, vice-president of General Motors Corp. and a past president of the SAE, found his home town of Loudonville, Ohio, "closed for the day" on Aug. 29 to celebrate with him his 70th birthday. Only the telegraph office remained open. The town's population was doubled when more than 4000 of his former neighbors and hundreds of industrialists wished him many happy returns with a Gay Ninety's pageant through bannered streets, barbershop quartets harmonizing "Happy Birthday to You," with all hands swinging lustily in the choruses, a raccoon chase replete with dogs, and a mammoth party on his homestead near the town. Besides the delegation of ten General Motors vice-presidents, scores of the nation's leading industrialists, and hundreds of business associates, his son Eugene, his wife and two daughters, a grandson, his brother Adam and sister Mrs. Daisy Hyde, were on hand to taste the cake.

MAURICE OLLEY, who returned to General Motors Corp. recently after service with the British Purchasing Commission, has sailed to England where he will take up his new duties as passenger car engineer of Vauxhall Motors, Ltd., Luton, Bedfordshire, England.

RAYMOND L. MORRISON, general manager of the Brake Division, Timken-Detroit Axle Co., has announced the acquisition of a 45-acre site at Ashtabula, Ohio, for a plant for brake and brake parts manufacturing. More than 500 will be employed at peak production, he said.

RICHARD COULTON BERKINSHAW, vice-president, general manager, and treasurer of Goodyear Tire & Rubber Co. of Canada, Ltd., was awarded commander of the Most Excellent Order of the British Empire by King George VI on the Dominion Day honors list.

F. O. TERRILL, general manager, warehousing and transportation, The Kroger Co., Cincinnati, announced a change in the company name from Kroger Grocery & Baking Co. to The Kroger Co.

ARTHUR L. BOEGEHOLD, head of the metallurgy department, Research Laboratories Division, General Motors Corp., has been nominated for president of The American Society for Metals. This nomination is tantamount to election.

Formerly in the U. S. Navy, the following men have taken civilian positions: **R. KENNEDY SMITH,** engineer, Graphite Bronze Co., Cleveland; **JOHN V. PETERS,** laboratory instructor, Mechanical Engineering Department, Iowa State College, Ames, Iowa; **J. A. WISELY,** Engineering Department, Propeller Division, Curtiss-Wright Corp., Caldwell, N. J.; **ROBERT M. SALTER, JR.,** research analyst, Aerophysics Laboratory, North American Aviation, Inc., Inglewood, Calif.; **ROBERT W. SCHROEDER,** design specialist, Powerplant Design Section, Glenn L. Martin Co., Baltimore, Md.; **CHARLES A. SILER,** design engineer, West Bend Aluminum Co., Hartford, Wis.; **JOSEPH C. FIREY,** assistant research engineer, California Research Corp., Richmond, Calif.

WILLIAM J. CUMMING has been made responsible for coordinating all phases of White Motor Co.'s General Service Department, such as Preventive Maintenance Programs, Unit Exchange, Repair and Overhaul Procedures, and Training Functions relating to all field service operations. The Field Service Division has been added to the other branches of that department, according to **F. G. ALLEN,** general service manager.

PAUL N. FOX, formerly quality manager of Atlantic Diesel Corp., New Brunswick, N. J., has been appointed administrative officer of Air Transportation for Korea. He will be located in Seoul, Korea, during 1947.

During the war years, **R. W. KEELEY** was general manager, Illinois Division, Bendix Aviation Corp., Chicago. With the termination of hostilities, Mr. Keeley returned to Bendix-Eclipse of Canada, Ltd., Windsor, Ont., Canada.

STANLEY P. CLURMAN has accepted an appointment as research engineer, Division of Industrial Cooperation, Massachusetts Institute of Technology, Cambridge. He had been employed as a stress analyst with Propeller Division, Curtiss-Wright Corp., Caldwell, N. J.

Formerly division engineer, Aerojet Engineering Corp., Azusa, Calif., **PROF. MAURICE J. ZUCROW** is now affiliated with Purdue University, West Lafayette, Ind., as an instructor of gas turbines and jet propulsion.

H. M. REIGNER has left the Engineering Division of Chrysler Corp., Detroit, to become a compressor development engineer, Aircraft Division, Packard Motor Car Co., Toledo, Ohio.

Since his release from the armed forces, **DONALD W. IRWIN** has accepted a position as engineer with the McDonnell Aircraft Corp., St. Louis, Mo.

After discharge from the U. S. Marine Corps, **THOMAS G. VALENTY** rejoined D. W. Onan & Sons, Minneapolis, as a mechanical engineer in the engine design section of the company.

LT.-COL. EDWARD GRAY, who had been Chief of the Automotive Division, U. S. Army Ordnance Department, Aberdeen Proving Ground, Md., has been transferred to Watervliet Arsenal, Watervliet, N. Y., where he has been assigned the position of works manager.

A graduate of Yale University, enrolled student **GARNER W. O'LEARY,** is now a junior engineer with Electro-Motive Division, General Motors Corp., Chicago, Ill.

V. C. REDDY, previously a lieutenant (j.g.) U. S. Navy, is now working in the Engineering Department, Detroit Diesel Engine Division, General Motors Corp., Detroit, Mich.

Formerly automotive adviser, U. S. Army, Ordnance Branch, Dallas, Tex., **MAURICE S. WILLIAMS** is now affiliated with Engine Builder-Associated Contractors and Engineers, Houston, Tex.

CHARLES A. BARESCH, previously a project engineer, Associated Aero, Engrg. & Research Corp., Trenton, N. J., has taken a position as design engineer, Packard Motor Car Co., Aircraft Division, Toledo, Ohio.

Until recently superintendent of automotive equipment for R. H. Macy & Co., Inc., New York City, **WALTER R. HERFURTH** has been appointed assistant to **WILLARD D. BIXBY,** vice-president in charge of automotive equipment of United Parcel Service of New York, Inc. The company recently contracted with the department store to make the latter's deliveries. Mr. Herfurth is chairman of the SAE Cold Weather Problems Committee, a T & M project.

C. H. MORRISON has been elected vice-president and appointed general manager of Pacific Sales, Ltd., Honolulu.

ALBERT E. WILSON has recently become vice-president in charge of engineering, Keal Industries, Cleveland, Ohio.

Upon completion of terminal leave, **WILLIAM J. WEBER** took a position in the experimental department, Casey Jones School of Aeronautics, Inc., Newark, N. J.

Prior to his return to Massachusetts Institute of Technology, enrolled student, **WALTER R. DERLACKI** served as an ensign in the U. S. Navy.

Formerly an enrolled student at the University of Wisconsin, Madison, and chairman of the SAE Student Branch on that campus, **GEORGE E. HLAVKA** is now employed as an engineer in the research and development department, Elliott Co., Jeannette, Pa.

Previously aeronautical engineer, North American Aviation, Inc., Inglewood, **FRANCIS N. BEAUVAIS** has become associated with Ford Motor Co., Manhattan Beach, Calif.

LEONARD B. SPERRY

H. S. MANWARING

CHARLES A. HUBERT

LEONARD B. SPERRY, formerly manager of engineering, Farm Tractor Division, International Harvester Co., Chicago, retired after 38 years of service with the company. Mr. Sperry contributed greatly to the development of Harvester tractors as well as having served with many committees in the industry. He has been an SAE member since 1920. **CHARLES A. HUBERT,** who came to International Harvester Co. in 1937, will succeed Mr. Sperry as manager of engineering. An active member of the SAE Chicago Section's Governing Board, H. S. MANWARING has been appointed manager of engineering, foreign operations, International Harvester Co.

JOHNSON

MILES E. JOHNSON has been elected first vice-president of the newly organized Melrotor Industries, Inc., Muskegon, Mich. He has been chief product engineer of Continental Aviation & Engineering Corp.

WHEATON

Formerly analytical chemist and chief metallurgist, Continental Aviation & Engineering Corp., CLARK E. WHEATON has been voted secretary of Melrotor Industries, Inc., producers of internal combustion engine and piston rings.

BOTTARO-LOPEZ

A. F. BOTTARO-LOPEZ, owner of a consulting engineering office for aeronautics, has accepted appointment to the Board of Directors, Aeroposta Argentina Airlines, Buenos Aires, Argentina.

HUNSAKER

JEROME C. HUNSAKER, head of mechanical and aeronautical department, M.I.T., has been elected a director of the Goodyear Tire and Rubber Co., it was announced by P. W. LITCHFIELD, board chairman.

HUBER

White Motor Co., Cleveland, has appointed FRED HUBER export service manager for the West Indies, Central America, and South America, with headquarters at San Juan, Puerto Rico.

BROWN

H. FLETCHER BROWN, who for 15 years was employed by Boeing Airplane Co., Wichita, Kan., has now taken a position as vice-president, production manufacturing, Boeing Aircraft Co., Seattle, Wash.

EVANS

ROBERT B. EVANS, vice-president of Evans Products Co., Detroit, has accepted appointment as Chairman of Michigan Aviation Week, to be held April 18-27, under sponsorship of the Aero Club of Michigan.

DORAN

After 27 years with General Motors Corp., FELIX DORAN, JR., resigned to enter retail motor car distribution in Dallas, Texas. A veteran of World War I and II, he spent 21 years with the Chevrolet Division. His company is Doran-Chevrolet, Inc.

ROBBINS

WOOLLARD

FRANK G. WOOLLARD, M.B.E., design and production engineer and industrial executive, has been re-elected president of the Institution of Automobile Engineers for his second term on the eve of the amalgamation of that organization with the Institution of Mechanical Engineers. Members of both Institutions have agreed to the merger. Founded in 1906, the I.A.E. has just observed its Quadragenary Celebrations. BRIAN G. ROBBINS, secretary of the I.A.E. since 1934, has returned to that position since he was released late in 1945 after more than seven years of British military service as a lieutenant colonel in the Royal Electrical & Mechanical Engineers.

GUY WESTON EMBREE is junior manager of Guy L. Embree Bus Transportation, Pasadena, Calif. He had been a mechanical engineer with Ames Aeronautical Laboratory, National Advisory Committee for Aeronautics, Moffett Field, Calif.

Works manager and automotive engineering consultant for 30 years, **E. N. SAWYER** has resigned as production engineer of Oliver Corp.

E. N. SAWYER

to go fishing and enjoy an unaccustomed leisurely life. A member of the Society for nearly 30 years, Mr. Sawyer has been active on SAE production, and tractor committees for a number of years.

DOUGLAS R. REMY, formerly product designer with North American, has taken a position with Chevrolet Cleveland Division, General Motors Corp., Detroit, as senior designer.

LT. WILBUR MARCUS, U. S. Navy, who had been assistant industrial manager of the Puget Sound Navy Yard, Seattle, has been appointed general manager of A. Marcus, Chicago, general merchandise wholesale firm.

Until recently a sales engineer for McQuay-Norris Mfg. Co., Detroit, **ROBERT W. RAGEN** is now sales engineer with Leininger Industrial Co., manufacturers' representative in that city.

Having served in the U. S. Army in the infantry, and later as senior inspector for the Navy's Bureau of Aeronautics, in Miami, Fla., **WALTER CHARLES THOMAS** is the Navy senior inspector of aircraft at Grumman Aircraft Engineering Co., Bethpage, Long Island, N. Y.

GERALD J. McCAUL, formerly affiliated with Allison Division, General Motors Corp., Indianapolis, as a project engineer, a position he held prior to his enlistment in the United States Army Air Corps, has now become associated with Taylor Turbine Corp., New York, N. Y. During his Army career, Captain McCaul assisted in the development of jet propelled fighter planes at Muroc Flight Test Base, Muroc, Calif., and for this service was awarded the Army Commendation Ribbon.

HERBERT L. TOLLISEN, JR., has taken a position as engineer, Boeing Aircraft Co., Seattle, Wash. Mr. Tollisen served as an ensign in the U. S. Navy before assuming his present position.

Previously project engineer, Bendix Products Division, Bendix Aviation Corp., South Bend, Ind., **JUAN E. CINTRON** is now experimental engineer with the same company.

Prior to his enlistment in the U. S. Army, **ROBERT R. ARBANAS** was an enrolled student at General Motors Institute, Flint, Mich.

CHIEH NGE WEN is currently a trainee, Chicago Pneumatic Tool Co., Franklin, Pa.

VICTOR H. BERNARDI has currently transferred from Office of Chief of Ordnance-Detroit to the Washington office.

Formerly an enrolled student at the University of Minnesota, Minneapolis, **ALBERT C. WALDVOGEL, JR.,** is now employed by Fulton Iron Works, St. Louis, Mo.

Previously owner, Whiting Engineering Co., Detroit, **CHARLES H. WHITING** is now employed by the Engineering Service Inc., of America, in the same city.

Prior to his association with the Ordnance Department, U. S. Army, Aberdeen Proving Ground, Md., as chief of the enlisted training section, depot and supply branch, the Ordnance School, **LT. EUGENE A. PETERSON** was a mechanic with International Harvester Co., Salt Lake City, Utah.

FRED C. ZIESENHEIM has been appointed sales manager of the Die Casting & Plastics Division, Hydraulic Press Mfg. Co., Mount Gilead, Ohio. He had been sales manager of Lester-Phoenix, Inc., Cleveland.

Formerly test engineer with Sterling Engine Co., Buffalo, **CARL T. WOZNICKI** is field service representative of that company.

FARR

WARREN H. FARR has been appointed vice-president in charge of manufacturing of Budd Co., Philadelphia, the name of the consolidated Edw. G. Budd Mfg. Co. and Budd Wheel Co. He was vice-president and general manager of Budd Wheel Co.

ACCINELLI

VICE-COMMODORE E. N. ACCINELLI has been appointed head of the Argentine Aeronautical Purchasing Commission in the United States and Canada, with headquarters in New York.

McCASLIN

H. C. McCASLIN, who had been chief engineer, Willys-Overland Motors, Inc., is now vice-president in charge of engineering, Kaiser Frazer Corp., Willow Run, Mich.

J. WARREN FRAME, III, is a sales engineer, Sprague Electric Supplies, Inc., Bridgeport, Conn. Mr. Frame has been employed as an experimental flight test engineer, Pratt & Whitney Aircraft, Division United Aircraft Corp., East Hartford, Conn.

OBITUARY

Adelbert William Putnam

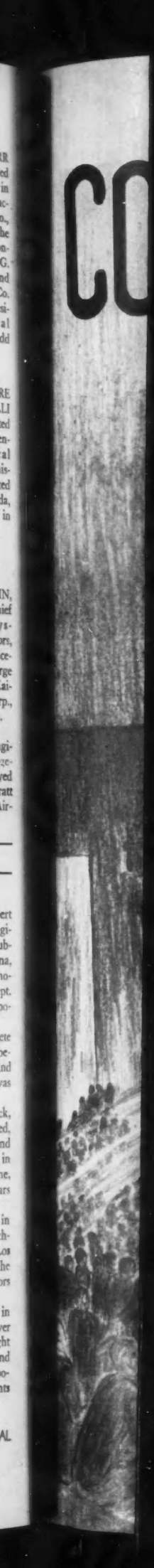
Treasurer of the Indiana Section, Adelbert William (Al) Putnam, and research engineer with the L. G. S. Spring Clutch subsidiary of Curtiss-Wright Corp., Indiana, and one of the nation's foremost automobile race drivers was killed instantly Sept. 15 in a dirt track accident at the Indianapolis State Fairground. He was 37.

His racing car crashed into a concrete wall during an AAA qualification run before 20,000 persons who crowded the grand stands and lined the track rails. He was driving at about 75 mph.

At the northwest turn of the mile track, his four-cylinder Palmer Special skidded, smashed through the outer railing, and struck the wall. He was thrown ten feet in the air. Only one car qualifies at a time, under the rules, so there were no other cars involved.

Born in Salt Lake City and educated in engineering at California Institute of Technology, he joined Kelman Electric Co., Los Angeles, as a foreman. Soon thereafter he was appointed plant manager of Orginators Co. of that city.

His professional racing career began in 1932, when he became an accredited driver for the AAA. He joined Curtiss-Wright Corp. after several years in production and tool design engineering work in Indianapolis, focussing his attention on improvements in racing cars.

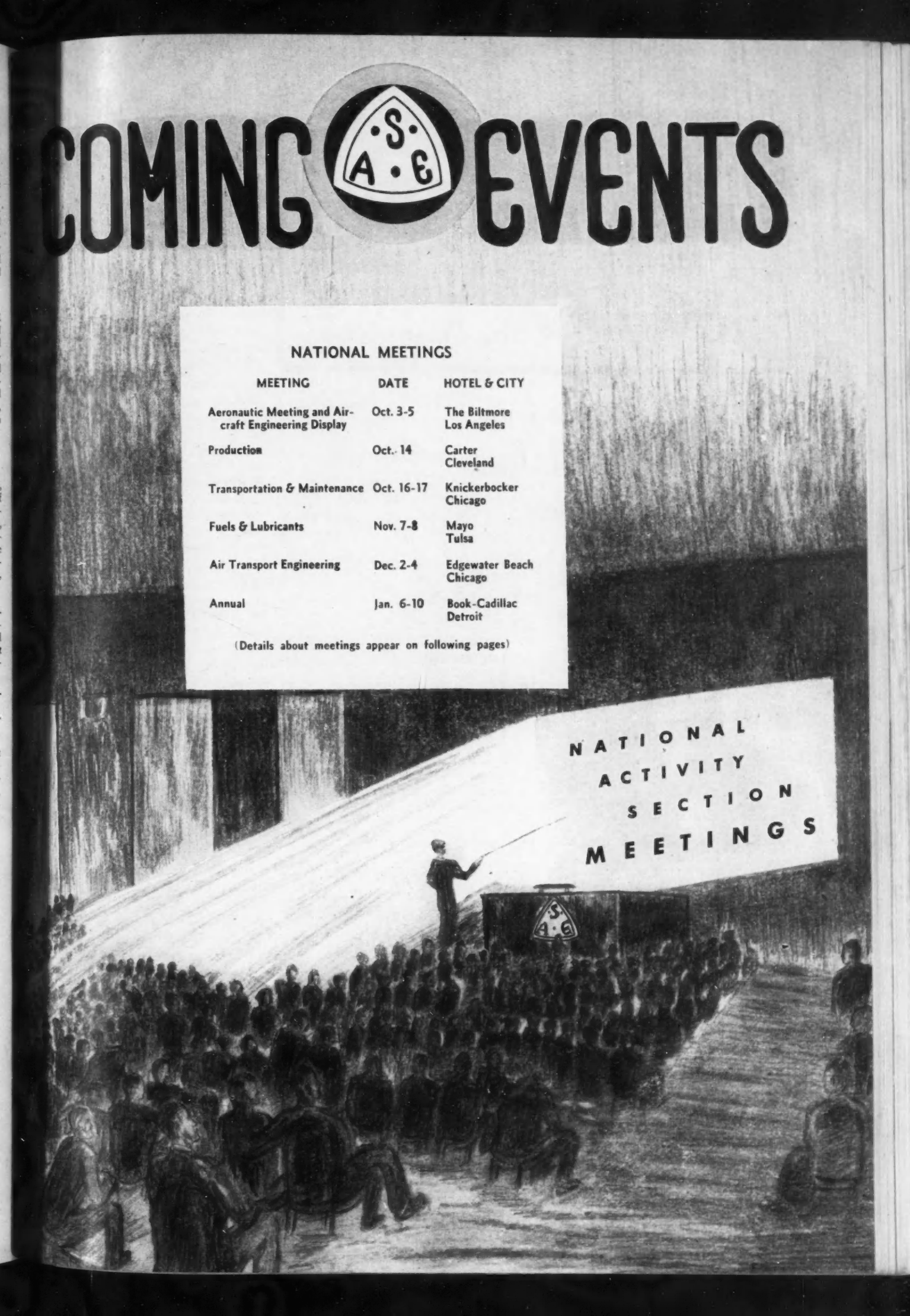


COMING EVENTS

NATIONAL MEETINGS

MEETING	DATE	HOTEL & CITY
Aeronautic Meeting and Aircraft Engineering Display	Oct. 3-5	The Biltmore Los Angeles
Production	Oct. 14	Carter Cleveland
Transportation & Maintenance	Oct. 16-17	Knickerbocker Chicago
Fuels & Lubricants	Nov. 7-8	Mayo Tulsa
Air Transport Engineering	Dec. 2-4	Edgewater Beach Chicago
Annual	Jan. 6-10	Book-Cadillac Detroit

(Details about meetings appear on following pages)



SAE National FUELS & LUBRICANTS Meeting

NOV. 7-8 • The Mayo, Tulsa

Program

THURSDAY, NOVEMBER 7

10:00 A.M.

F. L. Miller, Chairman

The Pour Point Stability Characteristics of Winter-Grade Motor Oils
J. G. McNab, D. T. Rogers, A. E. Michaels and C. E. Hodges, Standard Oil Development Co.

Effect of Crankcase Ventilation on Engine Deposits
H. L. Moir and H. L. Hemmingway, Pure Oil Co.

2:00 P.M.

J. B. Macauley, Jr., Chairman

The Bouncing-Pin Indicator is 25 Years Old
T. A. Boyd, Research Laboratories Division, General Motors Corp.

The Knockometer – A New Instrument for Fuel Rating
P. J. Costa and J. W. Wheeler, Sperry Gyroscope Co., Inc.

7:00 P.M. **DINNER**

J. C. Geniesse, Chairman

The Significance of Atomic Energy
Dr. H. B. Hass, Department of Chemistry, Purdue University

FRIDAY, NOVEMBER 8

10:00 A.M.

R. C. Alden, Chairman

Fuel Volatility – Its Effect on Performance and Distribution
W. L. Hull, University of Colorado, and Norman Parker, University of Illinois

Flight Tests of Aviation Oils
J. T. Hendren, Pan American World Airways

2:00 P.M.

A. G. Marshall, Chairman

Oil Filtration and Its Effect on Engine Wear
N. C. Penfold and D. S. Gray, Armour Research Foundation

Prepared discussion –
C. C. Butterworth, Chek-Chart Corp.

Oil Filters and Detergent Oils
O. C. Bridgeman and E. W. Aldrich, Phillips Petroleum Corp., and J. B. Romans, National Bureau of Standards

7:00 P.M. **DINNER**

J. H. Baird, Chairman

Wilbur Shaw
Dinner Speaker

President and general manager, Indianapolis Motor Speedway Corp.
"A Busy Day at Indianapolis"

■ ■

PLANS for the five remaining SAE national meetings are completed or are being finalized, Chairman Ralph R. Teetor of the Meetings Committee announced. These October, November and December events will bring the 1946 total of national meetings to 11.

As heretofore, the National Aeronautic Meeting, Oct. 3 to 5 in Los Angeles, will be accompanied by an elaborate Aircraft Engineering Display in Hotel Biltmore. Twenty-three technical papers have been scheduled for this three-day meeting, of which Dr. A. L. Klein is general chairman.

The three SAE professional Activities participating in this meeting are the Air Transport, Aircraft, and Aircraft Powerplant, of which W. W. Davies, Dr. Klein, and A. L. Beall are Meetings Committee chairmen, respectively. J. H. Kindelberger is in charge of the Aircraft Engineering Display, which is expected to have a wider range of displays than ever.

Large Group Cooperating

Working with four chairmen are their 38 meetings committee members, as well as members of the governing boards of the Southern California, Northern California, Oregon, and Northwest Sections. Their combined efforts are being exerted to bringing to SAE Members and other automotive engineers the most valuable aeronautic technical meeting in the Society's history.

Also cooperating in this meeting are the Aircraft Industries Association of America, Inc., headed by LaMotte Cohu, and the Air Transport Association of America, of which Vice-Admiral Emory S. Land is president.

Main problem of the committees which have the responsibility for the meeting has been to make the best possible selection from a vast array of suggestions to organize a well rounded series of technical sessions.

A feature of the Los Angeles meeting will be slow motion pictures of insects and birds in flight, and a demonstration of working models of ornithopters. Entertainment and a dance will round out the social phase of the three-day National Aeronautic Meeting.

Production Experts To Meet

Completed plans for the first postwar SAE National Production Meeting have been announced by Stephen Johnson, Jr., the Activity's Meetings Committee chairman.

His eight colleagues on the committee

DECEMBER 2-4
SAE NATIONAL
Air Transport Meeting
Edgewater Beach Hotel
Chicago

ogether with John R. Cox, Cleveland ection chairman, A. M. Rothrock, the ection's Meetings Committee chairman, nd members of the governing board of he section, have been working on the etailed arrangements. The meeting on ct. 14 will be held in the Carter Hotel.

The all-day meeting will close with a anquet.

National T & M Meeting in Chicago

Two days later the two-day SAE Naional Transportation & Maintenance leeting will begin in Chicago under the eneral chairmanship of Warren Tausig, chairman of the Activity's Meetings Committee.

Present plans call for at least eight arefully selected technical papers focusing the attention of motor fleet operaors on engineering developments calcuated to decrease transportation costs and o improve service.

Officers and members of the Chicago ection, host of the meeting, are working with Mr. Taussig in making the arrangeents for this meeting.

Tulsa Chosen for F & L Meeting

The Fuels & Lubricants Meetings Committee, headed by F. L. Miller, is inalizing the plans for the important nnual SAE event, the National technical meeting of petroleum technologists n Tulsa.

It will be a two-day meeting, beginning on Nov. 7, and will be held, as before, in the Mayo Hotel.

Eight important papers have been selected by Mr. Miller and his 11 fellow members. These have been chosen from a large list of suggestions, and this promises to be one of the most valuable fuels and lubricants meetings in SAE history.

As usual, the Activity Meetings Committee is relying heavily on officers and members of the Mid-Continent Section.

Air Transport at Chicago

Dec. 2 to 4 has been announced for the three-day SAE National Air Transport Engineering Meeting, to be held in Chicago. The Activity's meeting chairman, W. W. Davies, has arrangements well under way for this conclave of the leading air transport operating engineers of the country.

Fourteen papers have been selected for presentation at this important gathering, where attention will be focussed on new equipment design and economical operating procedures.

The Chicago Section, which always carries a large part of the responsibility for the success of this annual event, and has been largely responsible for the success of this meeting, is working with Mr. Davies and his committee of 10 leading engineers in the air line and equipment fields.

The meeting will be held again in the Edgewater Beach Hotel where adequate space can be had for the large attendance expected.

SAE NATIONAL

October 14
Carter Hotel, Cleveland

PRODUCTION MEETING

Program

MONDAY, OCTOBER 14

9:30 A.M.

J. E. Hacker, Chairman

What's the Matter with Cast Iron?
A. A. Weidman, Detroit Diesel Division, General Motors Corp.

Prepared Discussion

1:30 P.M.

Joseph Geschelin, Chairman

The Removal of Metal by Grinding
R. E. McKee, University of Michigan; R. S. Moore, Quaker Chemical Products Corp., and O. W. Boston, University of Michigan

Stephen Johnson, Jr.

•

General Committee Chairman

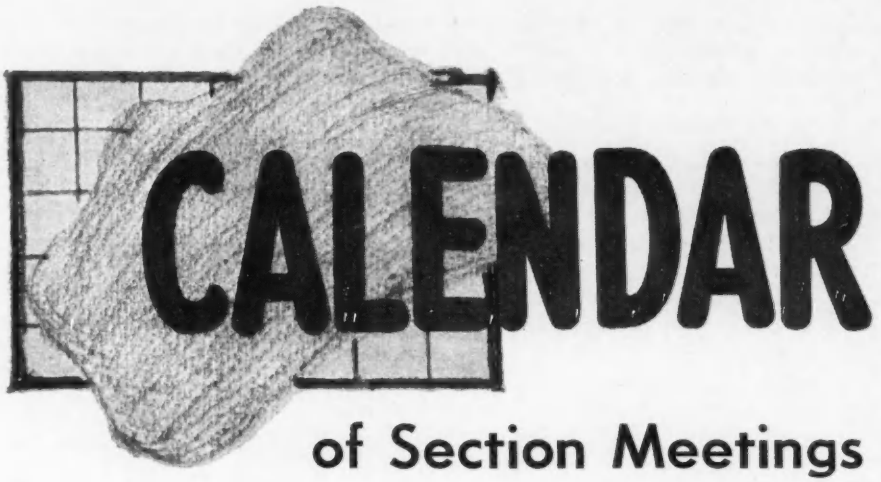
Management Control through Industrial Engineering
E. F. Gibian, Thompson Products, Inc.

DINNER—7:00 P.M.

Speaker: **CHARLES J. STILWELL,**
President, Warner & Swasey Co.

"The Much-Discussed Production"

SAE President L. Ray Buckendale



# of Section Meetings

Baltimore – Oct. 10

Engineers Club; dinner 7:00 p.m. Evolution of the Family Plane—G. M. Bellanca, president, Bellanca Aircraft Corp.

British Columbia Group – Oct. 9

Hotel Georgia, Vancouver; dinner 6:00 p.m. Speaker and subject to be announced.

Buffalo – Oct. 9

Worthington Pump and Machinery Corp., Buffalo Works—Inspection tour and Demonstration of Diesel Engines in Operation at Worthington Pump and Machinery Corp. Introductory Talk—W. E. Wechter.

Dayton – Oct. 15

Battelle Memorial Institute, Columbus; dinner 6:30 p.m. Meeting starts with trip through Institute—4:00 p.m. After dinner talks on various phases of work by members of Battelle Staff. Six subjects to be covered.

Detroit – Oct. 21

Horace H. Rackham Educational Memorial Bldg., dinner 6:00 p.m. Plastics—N. J. Rakas, project engineer, Chrysler Corp.

Indiana – Oct. 10

Antlers Hotel, Indianapolis; dinner 6:30 p.m. The Story Behind 1947 Studebaker Model—A. G. Laas, Studebaker Corp. Talk will be demonstrated with slides.

Metropolitan – Oct. 31

Hotel Pennsylvania, New York; meeting 7:45 p.m. Newest Trends in Helicopters—Frank N. Piasecki, Piasecki Helicopter Co. Robert A. Cole will preside as Vice-Chairman of Aeronautics.

Nov. 21—Transportation & Maintenance Symposium; Dec. 19—New Developments in Diesel Engineering; Jan. 30—Air Transport Engineering; Feb. 20—Symposium of New Developments in Passenger Car Components; Mar. 20—Aeronautics; April 17—Fuels & Lubricants Symposium; May 14—Transportation & Maintenance, and June 12—Diesel Engines.

Mid-Continent – Oct. 11

University of Oklahoma, Norman; meeting 7:30 p.m. Speaker and subject to be announced.

Milwaukee – Oct. 4

Milwaukee Athletic Club; dinner 6:00 p.m. Automotive Ignition—H. L. Hartzell, engineer, Delco-Remy Division, General Motors Corp.

Mohawk-Hudson Group – Oct. 15

Schenectady Airport, Schenectady; dinner 6:30 p.m. Inspection trip to General Electric Flight Test Hangar at Schenectady Airport.

New England – Oct. 1

Engineers Club, Boston; dinner 6:30 p.m. The Practical Helicopter—T. J. Harriman, Bell Aircraft Corp., will discuss proven field of helicopter application, with overall and detailed problems of construction and improvement. Motion Picture—The Modern Magic Carpet.

Northern California – Oct. 8

Engineers Club, San Francisco; dinner 6:15 p.m. Some Marine Diesel Installation Problems—J. W. Anderson, executive engineer, Atlas Imperial Diesel Engine Co. Guests—John A. C. Warner, SAE secretary and general manager; SAE President L. Ray Buckendale, vice-president, in charge of engineering, Timken-Detroit Axle Co.

Peoria – Oct. 28

Jefferson Hotel; dinner 6:30 p.m. Symposium—Off the Road Tires. Speakers from Goodyear Tire & Rubber Co., Firestone Tire & Rubber Co. and Caterpillar Tractor Co.

Oregon – Oct. 11

Imperial Hotel, dinner 6:30 p.m. Speaker and subject to be announced.

Philadelphia – Oct. 9

Engineers Club; dinner 6:30 p.m. The Roles of Detonation Waves and Auto-ignition in Spark-Ignition Engine Knock as Shown by Photographs Taken at 40,000 and 200,000 Frames per Second—C. D. Miller, Research engineer, National Advisory Committee for Aeronautics. Motion pictures.

Pittsburgh – Oct. 22

Brakes—Steve Johnson, Jr., Bendix Westinghouse Automatic Air Brake Co. Motion Picture—Principles of Airbrake Operations.

St. Louis – Oct. 8

De Soto Hotel; dinner 6:30 p.m. Grass Roots of What Patents Are; How They Are Obtained; What They Do Today—Prof. L. L. Koenig, Washington University School of Mechanical Engineering.

Salt Lake Group – Oct. 14

Newhouse Hotel; meeting 8:00 p.m. Synthetic Tires—James Williams, U. S. Rubber Co.

Southern California – Oct. 24

Biltmore Hotel, Los Angeles; dinner 8:00 p.m. Aircraft Approach to Automobile Body Design—Mac Short, vice-president, Lockheed Aircraft Corp.

Southern New England – Oct. 2

Bond Hotel, Hartford; dinner 6:30 p.m. The Future of Guided Missiles—Prof. H. Guyford Stevers, Massachusetts Institute of Technology.

Spokane Group – Oct. 11

Desert Hotel; dinner 7:00 p.m. Detergent Lubricating Oils in Diesel Engines—E. N. Klemgard, Pullman Tractor & Implement Co.

Twin City – Oct. 3

Curtis Hotel, Minneapolis; dinner 6:00 p.m. Latest Development in Bevel Gears—R. W. Doell, Gleason Works.

Washington – Oct. 8

Hotel 2400; dinner 6:30 p.m. Speaker and subject to be announced.

Wichita – Oct. 10

Design and Production of Small Type Personal Airplanes—Webster Moore, Engineering Department, Cessna Airplane Co.

Williamsport Group – Oct. 7

Lock Haven, Pa.; dinner 6:45 p.m. Pick-up Service—A. B. Schultz, chief engineer, All-American Aviation, Inc. Motion picture films.

MATERIALS

cont. from p. 75

bers in themselves do not possess all these desirable characteristics. The secret of imparting to them the various properties is known as compounding – the alloying of ingredients.

Rubber compounding has grown from an art to a science – thanks to the electron microscope. This device proved carbon black – just ordinary soot – the most important single item in rubber compounding. It offered for the first time a means of seeing the carbon black particle, establishing the tie between particle shape and size and rubber performance.

Visual studies revealed that small particles are the most desirable in compounding; that intermediate sizes are useful in controlling the hardness modulus; and that larger sizes stiffen the stock but do not provide much reinforcement. Microscopic examinations also showed that the more nearly round the particle, the better the compound will be.

It was found that there are different types of carbon black and that each gives the rubber a special property. For example, the high modulus furnace black shown magnified 7000 diameters in Fig. 1 is used for stiffer stocks. Note that all blacks tend to be spheres.

With much closer control over rubber properties now possible, rubber is being tailored for many new jobs.

New rubbers made possible the locomotive drawbar and coupler shown in Fig. 2 that may point the way to use of rubber for lighter automotive parts. Maximum load on the drawbar rubber parts is 500,000 lb and maximum movement under this load is 2 in. *(Gulick paper entitled "Just How Good is Man-Made Rubber When Used in Tires?" presented at SAE Pittsburgh Section, April 25; Stein paper entitled "The Future of Rubber in the Automotive Industry," presented at Indiana Section, April 23, 1946.)*

TIN

Digest of Paper By

C. E. HEUSSNER & E. T. JOHNSON

Chrysler Corp.

ENGINEERING ingenuity has responded to industry's cry for a means of becoming independent of an uncertain tin supply in today's strife-torn world. Messrs. Heussner and Johnson demonstrate that by redesigning parts, improving processing, and developing alternate materials, greatest tin savings were effected in these four major automotive uses of tin:

1. Copper alloys,
2. Solders,
3. Bearings,
4. Coatings.

Tin contributes several desirable characteristics to copper alloys. It increases hardness, toughness, and resistance to pounding; it facilitates sintering of powdered copper and strengthens the sintered product; it greatly increases corrosive resistance. These properties make tin valuable in the greatest single use of tin bronzes, namely, bushings and thrust washers.

Engineering studies indicated that the following tin-conserving measures could be effectively adopted with no loss in performance:

- Brass bushings or bronze bushings of decreased tin content were used for moderate service conditions;
- Solid bronze bushings were changed to steel-backed bronze;
- Hardened steel – Parkerized in some cases – replaced bronze in some thrust bushings and thrust pads;
- Plastic thrust washers were used;
- A method was developed to bronze coat steel thrust washers by successively copper plating, tin plating, and thermal diffusion;
- Bronze springs were redesigned for carbon steel during the war;
- Radiator corrosion protection was secured by heavy silver or cadmium electroplating. With nickel again available, 18-8 stainless steel can be used where economically sound.

Excellent joining qualities of tin-lead solders and ease of application of high-tin percentage solders resulted in the use of 2.85 lb of tin per car for this purpose alone prior to 1942. Body solders containing tin were used as a filling material to seal and smooth over welded joints, to fill dents, and improve contour of steel parts. They are usually applied by "tinning" the body steel, adding mush solder of the same composition to the joint, and smoothing it in place with an oil-coated wood paddle to prevent sticking.

Peculiarities of this operation demand special characteristics of the solder. Besides the obvious strength and fatigue resistance properties, it must form a good paint base and withstand enamel oven temperatures of 325 F. It must also have a long plastic working range and good workability, permitting applications on horizontal, vertical, and even overhead surfaces.

Research over the past five years has developed these unique requirements in two alternate materials. One saves ¾ of the tin previously used and the other eliminates it entirely. They both offer the added advantage of direct application to steel without preliminary "tinning" with a higher tin content solder. The low-tin body solder consists of 3.6 to 4.0% tin, 3.4 to 3.8% antimony, 0.3 to 0.5% silver, 0.03 to 0.7% copper, and the remainder lead. The composition of the non-tin solder is 4.5 to 5.0% antimony, 0.7 to 1.2% copper, 0.8 to 1.0% silver, and the remainder lead.

Tin-base babbitts impart to high-speed bearings good fatigue resistance, low coefficient of friction, good anti-scoring properties, and easy bonding to steel. But tin babbitts generally contain over 85% tin.

The metallurgist went to work and evolved a good 1% tin babbitt shortly after Pearl Harbor which drastically cut tin consumption for this purpose from a spread of .07 to 1.2 lb per car to within a range of .004 to .02 lb. This alloy – known as SAE 15 – is composed of 15% antimony, 1% arsenic, 0.5% copper, 1% tin and the remainder lead. Compared with the 85 to 90% tin-base babbitts, this represents a tremendous stride in tin conservation.

As a metal-coating material tin is desirable because of its corrosion-resisting properties and good solderability. Tin coatings for fuel system parts were originally selected as they did not accelerate gum formations in fuels. These coatings have now been replaced with electro-nickel and low tin-lead hot-dipped coatings. Tin coatings in hydraulic brake systems were considered essential, as they provided adequate corrosion resistance and did not react with brake fluids to form soaps. Modification of hydraulic brake fluids make it possible to eliminate entirely coatings from the brake system.

Dynamometer tests proved brass coatings on aluminum pistons a very satisfactory replacement for the tin scuff-resistant coating. This coating is made up essentially from sodium zincate, copper cyanide, free sodium cyanide, and basic lead carbonate. Composition and thickness of the deposit are determined by concentration of these constituents, bath temperature, and duration of immersion.

High pH and zinc concentration tend to inhibit the reaction, decreasing thickness of deposit. High copper or low zinc content tends to increase per cent of copper in deposit. The same effect is obtained by increasing the temperature

or time of immersion. Function of the lead appears to be passivation, controlling reaction speed.

These new processes and materials have shrunk tin consumption per passenger car from 4 lb in 1940 to less than 2 lb in 1945. But equally as important, they illustrate the value of the shakeup in our thinking. In addition to yielding large tin economies, they make for two other benefits – a superior product and appreciable cost savings. Toward what other goal could an engineer strive? *(Paper entitled "Substitutes for Tin in the Manufacture of Automobiles, presented at SAE Annual Meeting, Jan. 7, 1946.)*

See Two-Cycle Engine Powering Personal Plane

Digest of Paper By **J. L. RYDE**
McCulloch Aviation, Inc.

SUCCESS with two-cycle crankcase-scavenged engines on radio-controlled target planes refocuses attention on this type of engine for light aircraft, declares Mr. Ryde. In his description of the engine and its potentialities he discloses that:

The target plane engine had a bore and stroke of 3 x 3⅛ in. and was designed to operate on a mixture containing 92% by volume of 80 octane fuel and lubricating oil. Compression ratio was 7.2 to 1. Fuel specification was later changed to 91 octane and the compression ratio raised to 8 to 1. With the 80 octane fuel, the brake output was over 60 hp at 4000 rpm – corresponding to a bmep of over 68.0 psi.

Gears were eliminated from the design, accessories being driven from the crankshaft free end, as shown in Fig. 1. The generator mounted below the magneto is driven by a belt from the engine half of the magneto coupling. All moving engine parts and bearings are shown in Fig. 2. With the exception of the center main, all bearings are of the antifriction type. Overall engine weight less the generator and propeller hub is 73 lb, giving a specific weight of 1.22 lb per hp at its 60 bhp rating.

Although fuel consumption in this type of engine is high – due to inherent loss of charge out the exhaust port – 75% power corresponding to conventional engine cruising gave a fuel rate of 0.72 lb per bhp hr. Recent reports reveal attractive fuel economies of 0.60 per bhp hr and less obtained on highly developed units by careful valve and port refinements to minimize fuel loss in the exhaust.

Die casting possibilities of many parts offer substantial cost and weight reductions. Small bulk and ease of servicing are other items in its favor. Only four nuts – readily removable – hold the cylinder to the crankcase. Simplicity and low cost of servicing are exemplified in a top overhaul consisting of cleaning ports and rings as required.

Factors that have held the engine in disfavor up to now stand to be rectified by new developments. Lower price fuel injection equipment promises to improve economy and unstable idling characteristics. High frequency ignition systems can now fire a badly fouled plug, minimizing a serious design fault.

Techniques now on hand can eradicate objectionable features of this engine, enhance its good points, and give the small plane field the light weight and economical powerplant it is looking for. *(Paper "The Crankcase Scavenged Target Engine," presented at SAE National Aeronautic Meeting, April 1946.)*

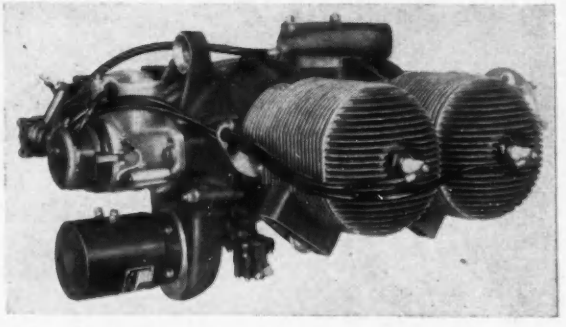


Fig. 1 – Accessories of the two-cycle target-plane engine are driven from the crankshaft free end

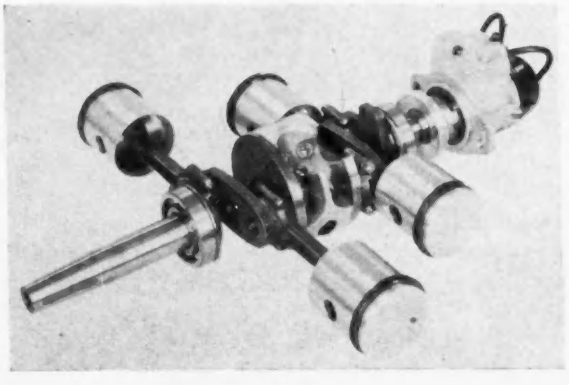


Fig. 2 – Moving parts of the two-cycle engine

Man-Made Ingredients Tailor Oil to Needs

Digest of Paper By **H. L. HEMMINGWAY**
Pure Oil Co.

PROSPECTS of meeting postwar engine lubrication demands are enhanced by war technology developments such as property-improving additives and synthetic products, reports Mr. Hemmingway. He points out that:

At the time of Pearl Harbor there were less than 25 additives and oil combinations in the SAE 30 grade with sufficient oxidation resistance to pass the 500-hr Series 71 Diesel Test and enough load-carrying capacity and detergency in the SAE 10, 20, and 30 grades to satisfy the Caterpillar test requirements. There are now between 100 and 200 series of oils which meet these requirements. Much has been learned about properties of oil stocks in engines.

Early war trend in arctic climates stimulated research on low-temperature performance. Effect of adding pour point depressant to a lubricant is shown in Table I. Solvent dewaxing in the refining should allow better control of maximum pour point.

Wartime development also created a relatively permanent additive for suppressing foam formation in lubricating oils. Use of foam suppressors will help in solution of diesel and gasoline foaming problems – including aircraft – as well as those in automotive gear oils.

"fluid drive" or torque converter oils, hydraulic oils, and various industrial applications.

Table 1 – Effect of Adding Increasing Amounts of Pour Depressant to 180-200 Viscosity at 100F Neutrals

Volume Percent Pour Depressant	Mid-Continent + 35F Original Pour	Mid-Continent + 5F Original Pour	Pennsylvania + 25F Original Pour
0.1	....	−25	....
0.3	− 5	....	−20
0.6	−15	−30	−30
0.9	−20	−30	B−30
1.2	−25	....	B−30
2.0	−30	−30	B−30
3.0	−30	B−30*	B−30
4.0	−30	B−30	B−30
5.0	−30	B−30	B−30

* B−30 means below −30F.

Requirements of aircraft hydraulic systems for oils of extremely low pour point and high resistance to viscosity-change over a considerable temperature range has resulted in development of effective and stable viscosity improvers. Their extended use in postwar engine oils depends upon how cheap and stable they will be.

War developments refocused attention on synthetic lubricating oils, especially German products. Synthetics possess desirable physical properties generally unattainable from natural petroleum with available refining processes with equally desirable performance properties.

Table 2 – Wholesale Quotations of Finished Lubricating Oils Compared With Basic Chemicals Used in Synthetic Oils

Finished lubricating oils	0.015 to 0.05
Paraffin wax – crude scale	0.04
– fully refined	0.06
Butyl alcohol	0.19
Cetyl alcohol	1.75
Ethyl hexyl alcohol	2.50
Methanol	0.09
Octanol	0.35
Castor oil	0.14
Chlorine (liquid)	0.05
Phenol	0.10
Sebacic acid	0.55
Soybean oil	0.11
Sulfur (refined)	0.015 to 0.03
Tallow	0.08

Regardless of their unusual assets, synthetics must compete on a cost basis with petroleum oils if they are to enjoy wide utilization. This hurdle is difficult for synthetics to overcome as their cost ranges from $0.25 to $1.00 per lb as compared with good mineral oil at $0.015 to $0.05 per lb. Even though manufacturing costs are drastically reduced, Table II shows, comparatively few basic chemicals can compare in cost with finished lubricating oil.

Despite their higher cost, synthetic oils will find use in special applications where their uses can be justified economically. Possible examples are:

1. Applications requiring little viscosity change over a temperature range and having greater resistance to congealing at low temperature such as aircraft hydraulic systems, hydraulic couplings, shock absorbers, and refrigerating machinery.

2. Applications requiring unusual lubricating ability at high temperatures or for long periods of time such as high-output electric motors where inaccessibility makes it desirable to seal in the lubricant for the life of the machine.

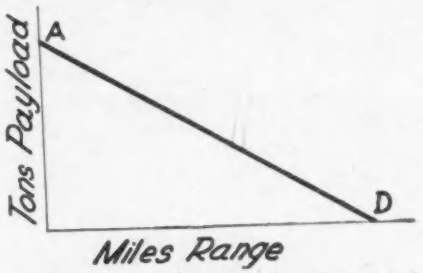
In few fields of commercial endeavor does the manufacturer of a commodity know less about the composition of the product he markets than does the petroleum oil refiner. But recent progress in study of lubricant composition and chemistry of its deterioration will assist the refiner in keeping pace with new engine requirements and meeting competition of synthetics. (*Paper entitled "Oil for the Postwar Car," presented at SAE Chicago Section, May 14, 1946.*)

Plane Efficiency Geared To Range Versus Payload

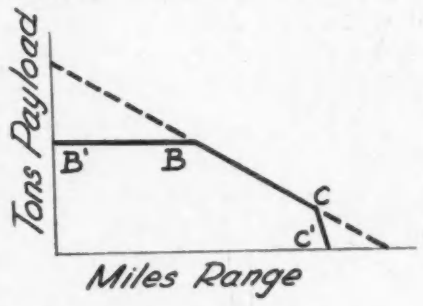
Digest of Paper By **G. S. SCHAIRER**
Boeing Aircraft Co.

EVALUATION of range-payload characteristics offers a measure of the transport airplane's efficiency for its designated route and type of service, says Mr. Schairer. He shows that:

Payload and range relationships readily are seen in graphical illustrations. Here, for example, is a typical payload chart for modern aircraft:



Point A represents the theoretical maximum payload for zero range and point D represents the *theoretical* maximum range for zero payload. But *in practice* this is the type of curve obtained:



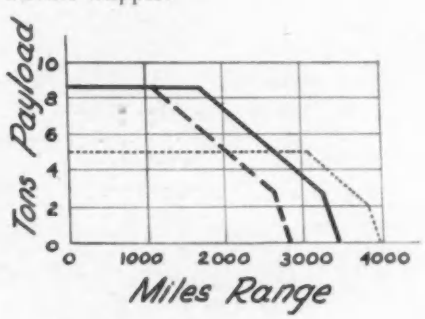
Theoretical maximum payload is generally limited to some lesser value as shown by line B′B because of payload space limitations and design landing weight. Similarly maximum fuel capacity limits theoretical maximum range to a value shown by line CC′.

The designer's principal objective is to arrive at a configuration that allows the airplane to operate near or at optimum efficiency most of the time. Excessive payload space limitations may be corrected by increasing the size of the body. But too much of an increase may so decrease range (due to added weight and drag) that a new and larger airplane may be required. Design landing weight also may be increased if the difference between take-off and landing weight is too great for a majority of operating ranges; but payload thus gained brings a corresponding increase in landing gear weight.

Where extreme long range is desired, maximum available range can be extended to approach the theoretical maximum by expanding tank capacity.

The ideal airplane would operate with all payload-range values falling at or near point B. If the values are nearer to B′ than B for most operations, the airplane would be more efficient with a larger body. Values nearer C than B indicate efficiency has been reduced by carrying a lesser payload over a greater range.

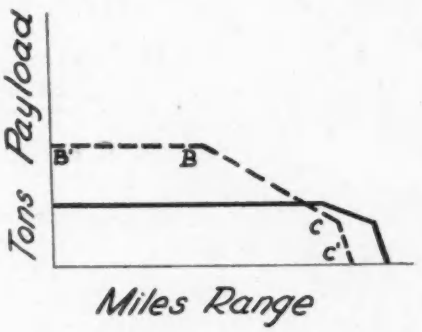
Utilization of this relationship is best shown by an actual illustration. Solid lines in this curve represent payload-range characteristics of the original Yankee Clipper:



Payload values shown did not include operator-furnished equipment – a considerable weight – and brought actual operating characteristics closer to the broken lines. Result was that on several occasions westbound flights from San Francisco to Honolulu were impractical in the face of unusually strong prevailing winds. Trans-Pacific schedules were disrupted pending abatement of strong westerly winds.

Efficiency of this airplane could have been increased for long-range flights by reducing the body size. Lower drag and lighter weight of a smaller body could have been converted into higher speed with smaller payload and increased fuel capacity. Such modifications – resulting in the dotted line – would have made westward flights possible under practically all conditions of prevailing winds.

Some operators are willing to use aircraft with characteristics shown by the solid line in this diagram as compared to the usual characteristics represented by the dotted line:



This stems from their desire to emphasize the very long-range characteristics of their transcontinental or transoceanic aircraft.

When long-range aircraft have characteristics indicated by the solid lines, extremely strong headwinds may reduce payload to nearly nothing, or still make very long-range, non-stop flights impossible. Headwinds have less effect on modern high-speed aircraft than on prewar models because they are exposed to headwinds for a shorter period of time. But operations at or near the point where the first downward break occurs in the curve are still subject to reduced payload penalty because of strong headwinds.

Long-range planes are efficient only for long-range operations because of the reduced payload capacity and additional fuel tank weight. While faster than the moderately long-range type, advantage of increased cruising speed virtually disappears in block speeds for short-range flight – particularly if the increase has been gained largely through increased altitude. (*Paper "Some Effects of Payload Vs. Range Characteristics on Transport Aircraft Efficiency," presented at Kansas City Section, Feb. 12, 1946.*)

Exhaust System Assumes Major Aircraft Role

Digest of Paper By
R. L. HAVER and H. A. GOODIN, JR.
Ryan Aeronautical Co.

EXHAUST gases have been transformed from a nuisance to the aircraft's propelling force, report Messrs. Haver and Goodin. In tracing exhaust equipment from its simplicity of yesterday to its complexity of tomorrow, they point out:

Early exhaust systems consisted merely of short, curved, mild-steel pipes serving solely to exhaust gases from the engine to the outside atmosphere. With increased power came the exhaust collector ring, dictated by a need for greater safety, improved comfort, and higher efficiencies.

Mild steel was found unsatisfactory when subjected to high temperatures and corrosive action of exhaust gases. The metallurgist remedied the situation with 18-8 corrosion-resistant steel and inconel, now widely used. Further design improvements were occasioned by the introduction of exhaust-driven turbosuperchargers for high altitude performance. Another configuration which arose was the individual-cylinder ejector stack that converted exhaust gas energy into jet thrust for added speed.

Presently being debated is the value of the exhaust or jet stacks versus the collector ring. Jet stacks have a prohibitive noise level that precludes their use for commercial operation. Cabin soundproofing materials have failed to reduce the noise level. Service life of the jet stack is shorter than that of the collector ring. Attempts to increase jet stack life have been successful, but led to complicated and heavier designs.

Future reciprocating-engine aircraft will use the collector ring for high altitude transport operations requiring exhaust turbine installations. Jet stack installations will be used on military aircraft where exhaust turbines are not required and where speed takes precedence over comfort and service life.

Exhaust equipment service life now looms important to aircraft operators. Strange as it may seem, average equipment service life today is no better than that obtained immediately before the war. This is due not to reduced quality of design, material, or workmanship, but to use of higher horsepower for longer periods with exhaust systems designed for lower engine ratings.

Crux of this problem is that increased horsepower ratings require larger exhaust systems to accommodate gas flow without excessive back pressures at exhaust ports. This reduces collector rigidity and increases weight. Best approach to improvements is considering the exhaust equipment at conception of the powerplant design.

With the advent of the jet engine, the exhaust system has become the major source of power – driving the plane by exhaust gas thrust. Exhaust system and turbine wheel absorb the jet thrust and transmit it to the airframe.

Of necessity this type of tailpipe is large in diameter. It must be mounted to accommodate large expansions while at the same time the thrust force must be absorbed. Since exhaust gases must be picked up at the turbine wheel, a fairing is provided inside the exhaust pipe to maintain smooth gas flow and to prevent the turbine wheel hub from overheating. Main problems to date center about suspension of the inner fairing and mounting of the long tailpipe.

Barrier to solution of future problems lies in the lack of better materials. Engineers are looking to metallurgy to answer their challenge so that low service life expectancy of present and projected designs may be increased. They want a material with a scale point above exhaust gas temperatures, increased tensile strength, and reduced carbon absorption rates. They also point out that extreme increases in thrust are obtainable in jet engines by using the reheat cycle. This entails operations at 3000 F and higher exhaust gas temperatures. Best materials today cannot operate successfully above 1300 F. Jet engine destiny rests with the metallurgist. (*Paper entitled "Design Trends in Aircraft Exhaust Systems," presented at SAE Annual Meeting, Jan. 11, 1946.*)

Atomic Energy Remote As a Practical Fuel

Digest of Paper By **PROF. J. R. DUNNING**
Columbia University

LITTLE likelihood exists that atomic power will ever replace our common fuels in most applications, says Professor

Dunning, although it will probably supplement existing methods. Much more development than has been achieved in the past remains to be done before atomic power finds wide constructive application.

Introduction of atomic fuels will depend partly on economics and partly on technical advantages of atomic energy.

Raw material availability is one limitation on its utility. Although uranium is as abundant as copper, its occurrence in high grade ores is not common. Continued prospecting for more ore deposits

and development of cheap recovery methods is essential if the cost of atomic power is to be reduced.

U-235 produces ideally about 11.5 million kwhr per pound. Approximate price per pound of U-235 to compete on an equal energy basis with other fuels ranges from $52,000 for aviation gas at 20¢ per gal to $9000 for coal at $6 per ton. Production costs of U-235 today are secret.

Professor Dunning points out, in consideration of practical atomic applications, that intrinsic temperatures developed in uranium fission are astronomical – in excess of billions of degrees. The immediate problem is how to utilize the high temperature possibilities effectively. Fortunately, the energy can be degraded and used at lower temperatures. Most industrial applications do not require highly concentrated U-235, so that the material will not be used in the highly explosive range.

Conventional type heat engines such as gas turbines can utilize atomic energy, he points out. Heat transfer problems and high temperature properties of available alloys set our present limits. Application to stationary powerplants and to large propulsion units such as ships seem readily practical in time with adequate research and development.

Jet propulsion devices for large airplanes and rockets likewise appear promising.

Radiation Limits Use

Radiation shielding of adjacent personnel from the enormous radiation of neutron and gamma rays is a serious problem because walls many feet thick are required at present. This seems to limit the immediate application to large units. Large planes may be equipped with atomic energy powerplants, but the possibility seems remote for small planes and cars.

How soon practical utilization is made of atomic power depends on the effort and the fund expended. Big strides forward have already been made and the long term future promises to be interesting. (*Paper entitled "Development of Atomic Energy," presented at SAE Annual Meeting, Jan. 7, 1946.*)

State Laws Restrict Designer Of Special Purpose Vehicle

From a Paper By **W. D. OWSLEY**
Halliburton Oil Well Cementing Co.

STATE regulations cramp oil truck designers in three ways: on height, length, and width – and the greatest of these is width. The fact that regulations vary widely from state to state makes the whole job even harder.

Actually, the laws governing vehicle height don't hinder the designer very much. If he keeps his vehicle under 12 ft overall height, it will be legal in all but one state. (Kentucky sets 11½ ft.)

Length regulations get in the way a little more. Length laws range from under 35 ft to 60 ft for single vehicles and from 35 to 65 ft for combinations. Legal maximums of less than 35 ft for a single unit and 45 ft for tractor-trailer units are a severe hindrance. These rules affect built-on equipment of cementing trucks, portable rigs with folding derricks, and bulk cement convoys. Not infrequently vehicle working space must be reduced below desired optimum to accommodate engines, tanks, pumps, and power transmission details to keep within the legal length.

Width restrictions impose the greatest load on the designer's ingenuity. Nearly all states limit overall width to the familiar 96 in. – which means that frame width can rarely exceed industry's undesirable standard of 34 in. A slightly greater width – such as the frequently advocated 102 in. – would permit design for better stability, easier riding quality, greater tire life, safer brakes, better steering gear, and improved engine installations.

Another problem of the special vehicle designer pointed out by Mr. Owsley was that of adapting the unit to the functional equipment it must carry. Location of various built-on machines and manner of attaching them to the frame are two important phases of this problem. (*Paper entitled "Problems of Special Motor Vehicle Design," presented at SAE Mid-Continent Section, March 22, 1946.*)

Needs, Not "Dreams," Shape Truckers' Wants

Digest of Paper By **F. R. NAIL**
Mack Trucks, Inc.

INTEREST in the trucking industry centers about its actual needs, not dreamy predictions of "things to come," says Mr. Nail. He observes that operators are concerned primarily with these three factors:

1. Styling,
2. Power,
3. Power transmission.

Styling is most directly approached by considering the truck as a production tool – a production tool socially acceptable in appearance and behavior on the highway. This tool justifies its existence by earning revenue for hauling material; it must be useful and efficient.

Style Influences Sales

A good looking model sells trucks for the manufacturer and trucking for the operator. The more trucks and trucking sold, the lower costs become. If pleasing to the public, the distinctively styled truck will be accepted on the highways with minimum prohibitions and permit economical operation.

Key to utility and efficiency is accessibility, enhanced by items such as better visibility, ease of entering and leaving cab, and driver comfort. Negotiating narrow city streets and jockeying into

loading platforms demand good rearward vision for the driver instead of his hanging out the cab window or door. Wide-angle windshields, which force the door location behind the driver, do not make for easy entrance and exit.

Smooth front ends have brought up in one continuous sweep both the front panel and windshield. The driver must be seated close to the glass for comfortable downward vision. He can sit over the front axle or ahead of it. Seating him over the axle requires raising the floor height. If he is ahead of the front axle, it must be pushed back considerably. Pushing him back penalizes the design in states regulated by the Bridge formula (load allowance based on axle spacing). For every foot between the front axle and the extreme front end, 600 to 800 lb in permissible gross load is lost. This loss takes a large bite out of the cab-and-trailer operator's potential revenue, although it is unimportant in a single unit.

Adequate power with reasonable top speed will reduce public resentment and restrictive legislation – but what constitutes adequate power and reasonable speed is a moot point. Most state laws permit a maximum of 50 mph, although a few allow up to 70 mph.

Horsepower requirements to overcome air and rolling resistance for a truck 12.5 ft high and 8 ft wide plus a 40,000 lb trailer are shown in Fig. 1. Horsepower to overcome air resistance begins to sky rocket above 40 mph, becoming 46% of total horsepower required at 50 mph. A speed at which the time saved no longer compensates for additional fuel consumed is unsound.

Determining Design Speed

Should trucks be powered to pull their load at 50 mph? Although it will satisfy the passenger car driver who damns the slow-moving truck on the level, another factor must be considered – speed on inclines.

Table 1 – Comparison of Incline Speeds of Engines Powered for Maximum Speeds of 50 mph and 70 mph

	50 mph Engine	70 mph Engine
3% grade	26.5 mph	48 mph
6% grade	16.5 mph	33 mph
10% grade	10.5 mph	22.5 mph

Table I shows grade speeds for this same vehicle at both 50 mph and 70 mph maximum level speed. Obviously grade speeds for the 50 mph engine are too slow; but the truck powered with the 70 mph engine gives satisfactory results. Value of the advanced performance is open to debate. The decision rests upon whether revenue gain from reduced haul time merits higher initial cost and increased tare weight.

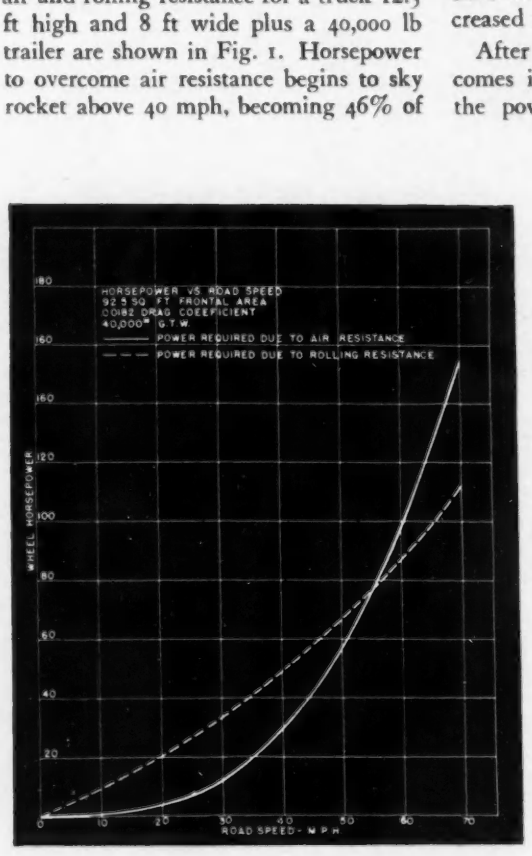
After the truck starts to run, it becomes important to get the most from the power created. The industry has lived with the gearbox converter for a long time and is looking to the hydraulic converter for improved efficiency. Truck work requires an extremely wide range of torque multiplication. A truck hydraulic torque converter – unlike that for an automobile or bus – requires a supplementing gearbox to cover this range.

Efficiency of one combination is shown in Fig. 2. Two gearboxes have been superimposed on this chart. Total available horsepower is represented by the area under the hyperbola and the cross-hatched area indicates total usable horsepower in a 5-speed gearbox. Ratio of these two areas shows an overall efficiency of 84.5%. Lost horsepower is shown cross-hatched.

Efficiency Boosted

By supplementing the 5-speed gearbox with an auxiliary, we get the steps shown by the dotted lines. Some of the lost horsepower has now been retrieved, upping overall efficiency of the low-speed gearbox to 91%. The more steps in the transmission, the nearer to 100% will be the efficiency. This is the goal of hydraulic torque converter development. But not for truck torque conversion – where an auxiliary gearbox is a must.

If the closely-spaced gearbox produces high efficiency but fatigues the driver in shifting, it nullifies its advantages. (*Paper "Prerequisites of Truck Design," presented at SAE Pittsburgh Section, March 18, 1946.*)


HORSEPOWER VS ROAD SPEED
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40,000# G.V.W.
POWER REQUIRED DUE TO AIR RESISTANCE
POWER REQUIRED DUE TO ROLLING RESISTANCE
WHEEL HORSEPOWER
ROAD SPEED - M.P.H.

Fig. 1 (left) – Power required to overcome both air and rolling resistance of a truck and 40,000 lb train

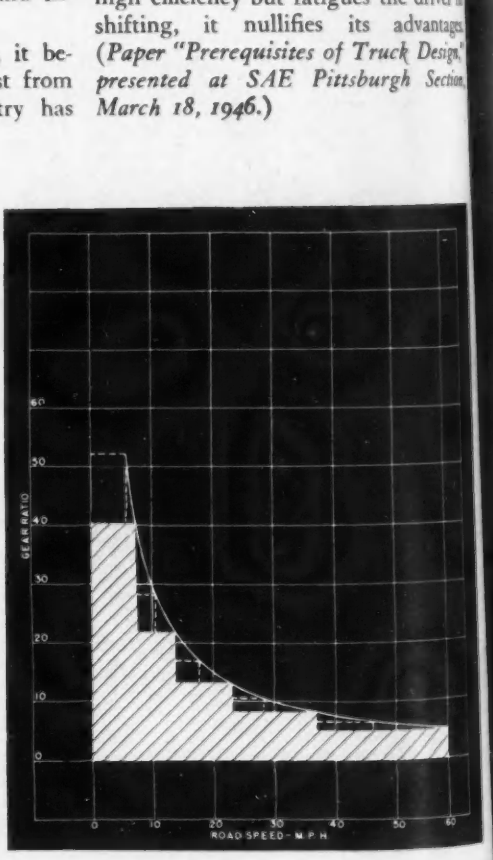


Fig. 2 (right) – Usable power for a 5-speed gearbox combination is shown by the cross hatched area. Supplementing this gearbox with an auxiliary ratio regains power enclosed by the dotted lines

Diesel Oil Chemistry Prolongs Engine Life

Digest of Paper By **F. W. KAVANAGH**
California Research Corp.

COMPOUNDING is bringing closer the ideal diesel oil that would allow the engine to operate forever without overhauling or makeup oil, advises Mr. Kavanagh. He shows compounding now lengthens engine life in these three ways:

1. Prevents deposits,
2. Reduces wear,
3. Reduces rust.

One way of eliminating deposits is to reduce the oxidation rate of the oil, preventing deposit of precursors – harbingers of other deposits. Effective oxidation inhibitors – used in all high quality heavy-duty and diesel lubricants – performs this function.

Deposits can also be eliminated by preventing solids from forming. This dispersant or peptizing property is identical to the action of soap which surrounds each tiny dirt particle and prevents it from sticking to others. Just as hand soaping cleans the hands and dirties the water, compounded diesel oils leave the engine clean but become dirty themselves.

It might be argued that the oil's peptizing action maintains abrasives in suspension, increasing wear. But millions of miles and thousands of hours of field tests have shown that this does not happen. Peptizing action is confined probably to small non-metallic and practically non-abrasive particles.

The third anti-deposit quality of compounded diesel oils is detergency – ability to react chemically with oxyacids, materials that form gums, varnishes, and binders cementing deposits to engine parts.

Compounded materials have reduced piston-ring and cylinder-wall wear to about one-fourth of that found for uncompounded lubricants. Reduction in wear is associated with adsorption characteristics of compounding materials and their ability to adhere to hot metal surfaces.

These materials will also reduce engine rusting to about 20%; but only if engine operating temperatures are maintained above the dew point of vapors present. Rusting is reduced by formation of a protective oil film on metal surfaces that does not drain off and is resistant to displacement by water.

Need for makeup oil stems from gradual consumption of compounding materials. Oxidation inhibitors are used up by preferential reaction with active oxidation.

Peptizing is an adsorption reaction similar to aging of whiskey in a charred barrel. In this case heavy alcohols and other impurities migrate and attach themselves to the charcoal surface area by a process of selective adsorption. Whereas good separation here may take several years, diesel oil compounding materials are adsorbed much more rapidly on dirt particle surfaces. When adsorbed on the particles, the compounding is rendered inactive for surrounding other particles. The oil eventually becomes deficient in compounding material.

Each chemically-detergent compound molecule also functions only once. Rate of compound consumption is proportional to the rate of formation and reaction of oxyacids.

High-speed diesel lubrication requirements could not be met without compounded oils. (*Paper "Diesel Engine Lubricating Oils," presented at the SAE Northern California Section, May 25, 1946.*)

Aircraft Icing Revelations Lighten Trying Tasks of Designer and Pilot

Digest of Paper By **C. M. CHRISTENSON**
United Air Lines, Inc.

STUDYING how ice forms in flight can aid the engineer in designing the airplane and perfecting anti-icing equipment and the pilot in minimizing ice formations during flight, declares Mr. Christenson. In flight tests he conducted he found that:

Equipment necessary for these investigations is:

a. Aluminum tubes – .75 in. and 1.50 in. x 15 in.,
b. Pyraline streamline section,
c. Airfoil sections,
d. Weston dial thermometer.

Best procedure is to expose the desired section through the side cockpit window while flying through an icing condition

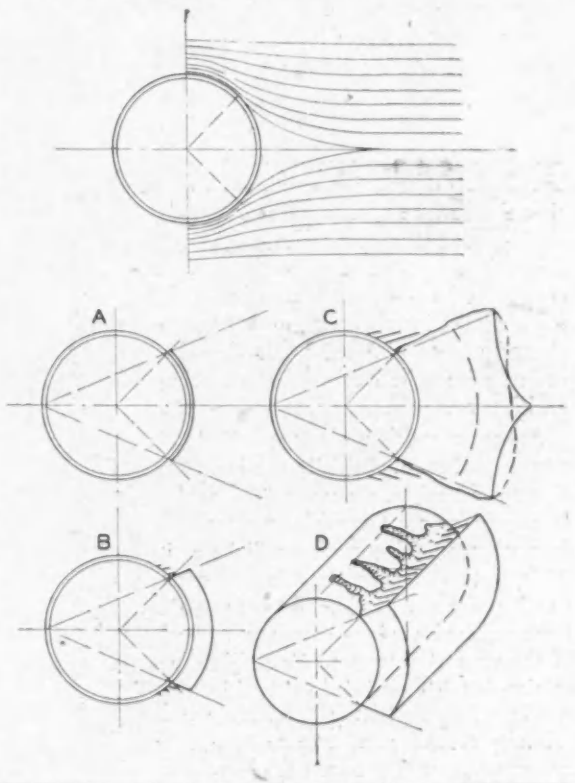


Fig. 1 – Ice formations about a tube in flight

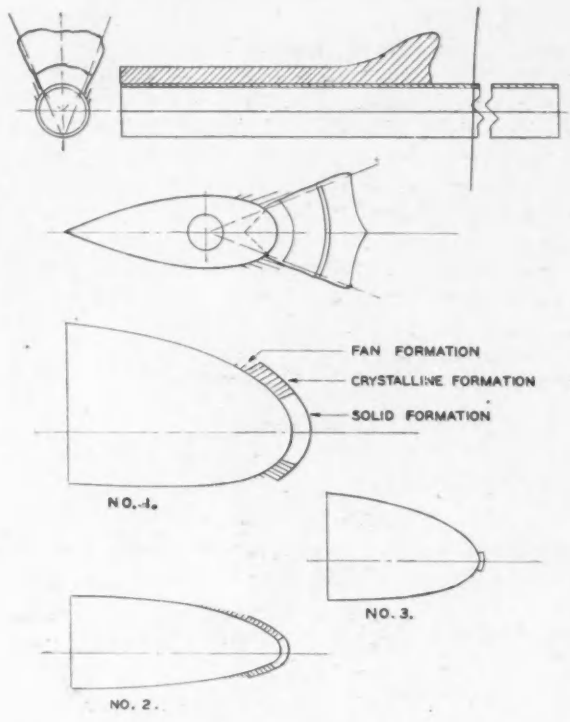


Fig. 2 – Average ice formations formed on various sections

and to withdraw it at intervals of from one to ten min for measurement and study. The airfoil section was also held at various angles of attack to determine the rotation of the section with a change of pressure distribution about the section.

Kinds of Ice

Observations indicate that ice types are best defined by their process of formation – crystalline and filming – rather than by the popular terms "rime" and "clear" ice. Basic difference between the two is that the surface of crystalline ice is dry during formation and film ice is wet. Dissections of various sections show crystalline ice to be made up of irregular ice crystals interlocking to form fan-shaped masses. Filmed ice is clear like ordinary ice – the kind the iceman brings on Monday.

Approximate flow about a cylinder is shown in Fig. 1. Initially the ice accretion form surface, shown in "A," is dry. If conditions are favorable to crystalline formation, initial accretion will be as in "A"; if time rate of freezing is great, small rivulets will flow back over the form to a point which may be well back of the vertical diameter. Crystalline formation is fairly well defined by Fig. 1.

This series of tests demonstrated that ice will accrete from a single point of adhesion, such as a rivet head, in a fan-shaped mass. It builds directly in the airstream and will continue growth or merge into the parent formation.

Crystalline ice formation obviously destroys the form profile. Initial accretion creates small eddies along the form boundary. Eddies carry droplets to the form surface creating points of adhesion from which new ice fans grow. Distortion of the airfoil form on a wing or propeller drastically changes aerodynamic characteristics. For this reason it is important to design anti-icing equipment to prevent initial ice accretion.

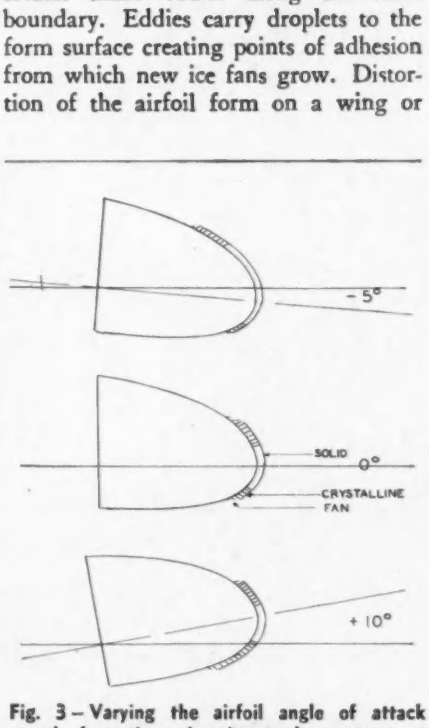


Fig. 3 – Varying the airfoil angle of attack reveals formation migration to be greatest at the negative angle of attack

Whereas small droplets and low temperatures are conducive to the crystalline process, the filming process flourishes on large droplets and high temperatures. As the temperature rises or particle size increases, the outer surface becomes wet enough to sustain a film of liquid water. Glazed ice accumulates as the droplets film and freeze rapidly enough to prevent flow. This process is duplicated by small drops of water falling on a dry ice cube.

If the rate of freezing is very low, the coalesced drops will continue growth until flow back occurs. Splattering and flow of the fluid surface will cause extreme roughness and great variation in the formation section. Section in Fig. 2 "C" has experienced both processes. Average crystalline formation is depicted by the dotted line and average filmed ice by the solid line.

Fig. 2 shows average accretions found on sample test sections. Rather interesting is the increased thickness of the formation near the fuselage – due to greater density of droplets in the boundary layer. In almost every case it was found that the accretion in normal flow is about 1/3 the accretion one in. from the fuselage.

Data on ice rotation with variation in angle of attack is shown in Fig. 3. Comparison of the formations reveals that accretion migration is related to the variation of pressure distribution and airflow about the section. Note the much thicker ice section at −5 deg as compared with those at 0 deg and +10 deg. This information tells the pilot flying through icing areas to maintain the airfoil as near to 0 deg angle of attack as possible if anti-icing equipment is not available.

Results of these preliminary studies and actual experience make mandatory the design of airline equipment eliminating unreliable stall characteristics in the presence of ice. Control surfaces and their attachments should be designed to forestall dangerous ice accretion. Continued development of effective anti-icing equipment is vital to flying safety. If ice is prevented from forming, the hazards it presents and problems of removal are bypassed. (*Paper entitled "A Report on the Nature of Ice Formation on Aircraft as Related to Airline Operation," presented at SAE Southern California Section, Nov. 1, 1945.*)

Radar No Panacea In Air Navigation

Digest of Paper By **CAPT. H. C. GULBRANSEN**
Pan American Airways, Inc.

DEPENDABLE navigation cannot rely on any single means such as radar to the exclusion of others, notes Captain Gulbransen. He shows that:

Early confidence in radar as the Aladdin's lamp of navigation was misplaced. Navigators relaxing on dead reckoning soon found that a comparison of the radar picture and the map did not always give a true fix. Often two different localities with similar arrangements of towns, rivers, and land patterns look alike in the radar scope and fool the navigator – especially if unpredictable winds are encountered.

Folly of relying solely on radar was proven by the bombing of Switzerland by American planes because of a radar navigational error. Dead reckoning would have prevented this mishap.

Radar is a wonderful navigational aid – but not for spot pilotage. It is excellent for supplying basic navigational information such as ground speed, course, and winds aloft under any conditions.

Capt. Gulbransen also discussed the history of air navigation, instrumentation, and the relationship of the navigator to the rest of the crew. (Paper "Transoceanic Air Navigation," presented at SAE National Air Transport Meeting, Dec. 5, 1945.)

All-Weather Flying Needs Adequate Approach Lights

Digest of Paper By **E. A. CUTRELL**
American Airlines, Inc.

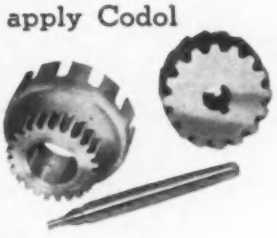
AIRPORT lighting for weather landing is due for an overhaul if airlines are to accelerate schedules to accommodate expanded business, maintains Mr. Cutrell. He points out that:

Appearance of approach lights at night from a mile or more is no indication of what they will look like in heavy weather during the day from ⅛ mile through a DC-4 windshield. Reports of bad weather daylight approaches reveal that posts on which lights were mounted often could be seen before the lights themselves were visible.

All-weather flying demands these four characteristics of approach lights:

CODOL Liquid Grinding Compound has often proved to be the primary factor in turning an unacceptable performance into a complete success. One user says: "When Codol replaced another fluid for grinding a crankshaft, wheel life jumped from 14 to 20 pieces and gumming disappeared." Says another: "Of seven compounds tested, Codol produced the best finish." And another: "Since standardizing on Codol for surface grinding, wheel and segment life has improved and rusting has been eliminated."

A Stuart Engineer will help you apply Codol to your advantage, whatever your grinding problems may be. Ask him to visit you.



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Stuart Oil Engineering Goes With Every Barrel

1. A part of the light should flash periodically;

2. All lights should be in a single row leading directly to the runway;

3. A part of the light should be red to contrast with runway lights;

4. Runway lights should be distinctive in shape for positive identification.

A system with two types of lights would meet these requirements – one being a flashing condenser light and the other a ladder-like neon unit. With these characteristics approach lights serve as threshold lights identifying location and bearing of the runway by day or night in poor visibility. They will allow time to lower flaps and adjust alignment and altitude for landing once the end of the runway is reached.

Only by taking cognizance of the importance of this lighting can the air transport industry adequately equip airports for all-weather landing. (*Paper "All-Weather Flying Facilities," presented at SAE Annual Meeting, Jan. 21, 1946.*)

Below: White Motor Truck, Model W. A. 22—BLOOD BROTHERS Equipped.
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Maintenance Tailored To Diesel Operation

Digest of Paper By **J. D. BELSKY**
N. Y. City Transit System

DEPARTURE from a diesel engine manufacturer's maintenance recommendations is sometimes called for in bus operation, Mr. Belsky believes. His operating experiences range from broken crankshafts and piston-ring sticking to burnt valves despite close adherence to manufacturers' procedures.

To meet bus schedules, he had to start a specially tailored maintenance program. By reducing exhaust temperature 18%, he managed to eliminate cracked cylinder heads and sleeves and burning of cylinder-head gaskets, valves, and turbulence chambers. Oil and filters were better after 3000 miles of operation with this change than after 1500 miles before the modification.

Exhaust temperature reduction was achieved by drilling and tapping all exhaust manifolds for a ¼ in. pipe plug about 2 in. above the exhaust pipe flange. The resultant 11.5% loss in power output had no effect on road schedules.

This and other changes including a maintenance and operation training program prolonged engine life from 25,000 to 40,000 miles before overhaul and eliminated recurrent parts failures. (*Paper "The Development of a Diesel Maintenance-Training Program," presented at SAE Metropolitan Section, May 21, 1946.*)

German National Airline Dated by Our Standards

Digest of Paper By **O. E. KIRCHNER**
American Airlines, Inc.

GERMANY'S pre-war air transport industry with all its eggs in one basket – the government subsidized "Luft-Hansa" or air union of cities – was years behind American air commerce, reports Mr. Kirchner. As a member of the Technical Industrial Intelligence Committee in Germany he uncovered interesting information on Luft-Hansa operations and engineering. Highspots of his report disclose that:

Balance sheets for 1939 revealed the Luft-Hansa to be a complete financial "flop." Revenue totaled only 50% of the company's operating expense. Passenger fares made up 70% of the revenue. Government subsidy furnished the remaining 50%. Were it not for the German policy of sending mail by air whenever possible together with a reciprocal international agreement on the exchange rate, still greater tapping of the government till would have been needed.

Fares were as high as the traffic would bear . . . 8¢ per mile. Charging twice the prevailing American rate, the company was "in the red" while our airlines showed a profit at that time.

Airplanes and engines varied widely; the backbone of the fleet was outmoded equipment of the Ford "Trimotor" era. Luft-Hansa's workhorse was the Junkers 52, first developed in 1928. About 70 to 80 of these airplanes were operated before the war. Accommodations in these planes were poor by our standards although frequent design changes were made in an attempt to modernize. The Junkers 86 – a diesel powered plane – flew only on transoceanic operations since diesel airplanes showed payload benefit only on long flights.

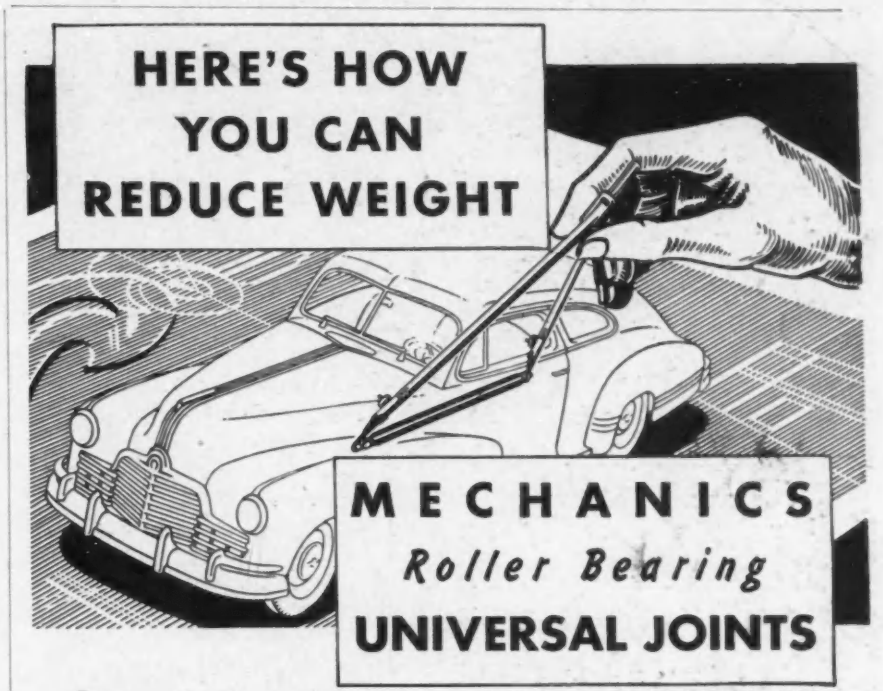
There was no air traffic control as we know it. Decision to take-off and selection of cruising altitude and course was left to the pilot. Since most operations were short daylight hops, this system proved satisfactory. Weather data were supplied by the government meteorological service. Germans were more than adequate in this field, the weather service achieving 80 to 85% accuracy in their predictions.

Retarded maintenance production stemmed from a failure to standardize equipment. Major factor defeating standardization was the large variety of airplane and engine models. Longest flying time on any one plane was 17,000 hr as compared to 27,500 hr on many of our planes despite more frequent inspection and repair of German aircraft. Engines were overhauled every 600 hr and oil changed every 50 hr whereas American practice averages 800 hr between engine overhaul and 200 hr for each oil change.

Engineering-wise, the piston of the Junkers Jumo 205 diesel engine proved interesting. It is a 3-piece piston consisting of an alloy steel plate crown, a solid but floating ring between the crown and piston body, and the main piston body. Four through-bolts held the assembly together. Overstressing due to differential expansion of the steel bolt and aluminum skirt caused bolt breakage. This was overcome by a heavy helical spring under each nut. As the piston expanded, the springs compressed and did not overstress the bolt. Excellent combustion and low fuel consumption were claimed for this unconventional piston design.

The electrical versus hydraulic controversy had been settled to the satisfaction of most German designers by the end of the war. They believed a combination of both methods solved the problem. Large powers and forces were transmitted hydraulically but controlled electrically; units needing smaller powers and forces were controlled and operated electrically.

Mechanical instruments were inferior in performance, workmanship, and materials to American standards. But their electrically operated instruments were good and occupied less space than ours. One electrical instrument that attracted wide interest was a propeller-pitch indicator. Its dial was calibrated like a clock



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in hours and minutes instead of degrees or rpm. Operating range instructions referred to limits in terms of clock time – such as 12:00 o'clock for starting. Not only did it eliminate the usual confusion between blade angle and rpm, but it also gave continuous indication of power for each engine of a constant speed propeller aircraft.

Much German engineering effort and money was allocated for deicing research. Evolved after much experimentation was a trend toward the heated wing, alcohol for propeller deicing, alcohol and electrical heat for windshields, and heat for carburetors. In one of three wing-heating systems developed each outboard engine supplied heat to the corresponding wing tip. Heat from the inboard engines was carried to the stabilizer leading edge.

A second system used exhaust from three cylinders mixed directly with fresh air; but the baffles clogged with soot. The third method introduced electrical heating for wing deicing. Leading edges of the wing and stabilizer were [illegible] with three parallel strips of silk [illegible] carrying the heating wires. Current [illegible] fed in cyclic sequence; the first strip [illegible] the airstream was charged first and [illegible] on for a three minute cycle. A fourth strip located directly under the leading edge operated continuously. Source [illegible] power for the system was a separate 24 [illegible] generator of 3000 watt capacity.

Terminals and airports are worthy [illegible] mention as German conception of [illegible] ideal airport directly opposed American thinking. Little importance was placed on the field's capacity for rapid traffic handling in all kinds of weather. Fields were small, less than a mile long. Soft surfaces instead of runways limited operation of heavier aircraft to most favorable weather conditions.

On the other hand, terminals and accompanying buildings were lavish. Their capacity was far beyond that of the fields. Making airfields the nation's showplaces was an important revenue-producing scheme. The public was encouraged to make the air terminal a favorite meeting place for dinner and entertainment and air shows were frequently scheduled.

The one fixed impression this study leaves is that American air transportation is second to none in passenger safety and comfort and efficiency of operation. (*Paper "A Report on the German Commercial Airline The Deutsche Lufthansa," presented at the SAE Annual Meeting.*)

■

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Tractor Meeting

cont. from p. 29

tive than an equal straw rack area. Examination of many current combines shows that this area is not being used to the best advantage.

In 1938 John Deere Tractor Co. undertook to produce a power shaft dynamometer to assist in the development of the "straight through" combine being produced experimentally. This was of the planetary reaction type, generally similar to the torque measuring equipment used on aircraft propeller drives. This equipment avoided the inertia effects and their errors inherent with any device using mass to balance out either forces or spring loads. The use of this equipment

during 1939 and 1940 led to the scientific determination of combine power requirements and the means by which they may be best reduced.

B. W. Keese, Wisconsin Axle Co., spoke of a power-take-off in which tractor propulsion is secondary and which uses the full motor power and by-passes the transmission. He said that the idea is not new but many companies have not had an opportunity of projecting a new design. The equipment has a master and secondary power take off mechanism which permits disengaging the master clutch or forward movement without stopping the internal operation of the combine.

Farmers, Prof. McCuen said, would welcome a separate independent clutch on lighter equipment for power take off so that the combine can clear itself. This would be the same as a self-propelled combine.

Second Paper – Power Requirements of Self-Propelled Implements, by John Borland, Clark Equipment.

John Borland discussed the problems which differences in soil and grade introduce into the power requirement aspects of the design of self-propelled implements. The Clark Equipment Co. engineer in his paper on "Power Requirements of Self-Propelled Vehicles," reviewed all existing data he could find and has made it available for design engineers. During discussion it was emphasized that without such data the engineer has little choice but to design for peak conditions. While the mechanism must be capable of handling peak loads for short periods, it is obvious that to design the unit for peak loads continuously will result in an unnecessarily heavy and expensive machine.

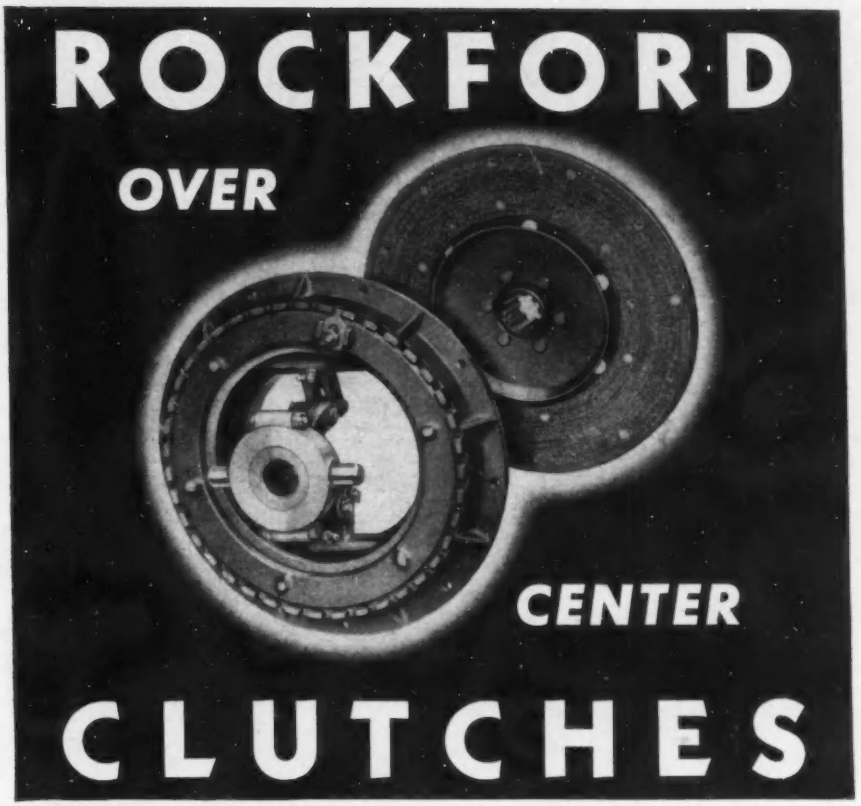
The self-propelled implement is a relatively new development and until a backlog of experience is accumulated similar to that on the tractor, new designs cannot be based on past practice with any assurance that an economical result will be obtained.

The four factors constituting resistance to movement of an implement are rolling resistance of the tires, resistance of the work being done, grade resistance and air resistance. Air resistance is so low as to be disregarded on a combine because of the low speeds. However, the author gave data and information gathered from many sources on the other three factors. Mr. Curtis said, during discussion, that bearing manufacturers must know how many years of operation are required, what percentage of the time a self-propelled combine will operate, and what percentage of the time will be on grades or in bad soil.

Problems encountered in the operation of shovels, excavators and other power equipment are quite similar to those of implements, and therefore power can be measured by similar methods, declared the three authors of a paper on "Equipment for Separately Measuring Power." The trend is toward electrical torque measuring devices having electrical resistance type of strain gages. The strain gage used in the torque meter described was designed by Dr. A. C. Ruge, co-author of the paper. Dr. J. H. Meier, another co-author, held that if engineers are satisfied with 3% error, a torque meter can be built using the ordinary strain gage.

In the group of torque measuring devices employing electric current in some form, the paper noted the following: Inductive, Capacitative, Magneto-strictive, Phase-sensitive, and Resistive.

The Inductive group employs the conventional electro-magnetic (reluctance)



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strain gages and slip rings. In the Capacitative group are a few experimental devices using high-frequency AC and variable air-gap condensers. The Magneto-strictive have not been commercially possible because of attendant hysteresis and variations due to temperature changes. The Phase-sensitive type usually employ generators spaced some distance apart on the torque carrying member.

The bonded resistance wire strain gage used in the Resistive type which is of chief interest in this paper, is based on the physical properties of alloys of experiencing a change of resistance to the passage of current with the change of strain. The advantages claimed for it are small physical dimensions; negligible mass inertia and centrifugal forces; ease of application and steady state of calibration serviceable under varying conditions. Its disadvantages include the necessity for slip rings and brushes. It was claimed that these limitations have been largely removed by special circuits and proper electronic amplifiers.

Brushes, brush holders and a number of methods of mounting the device at any convenient point in the power train was described.

DISCUSSION

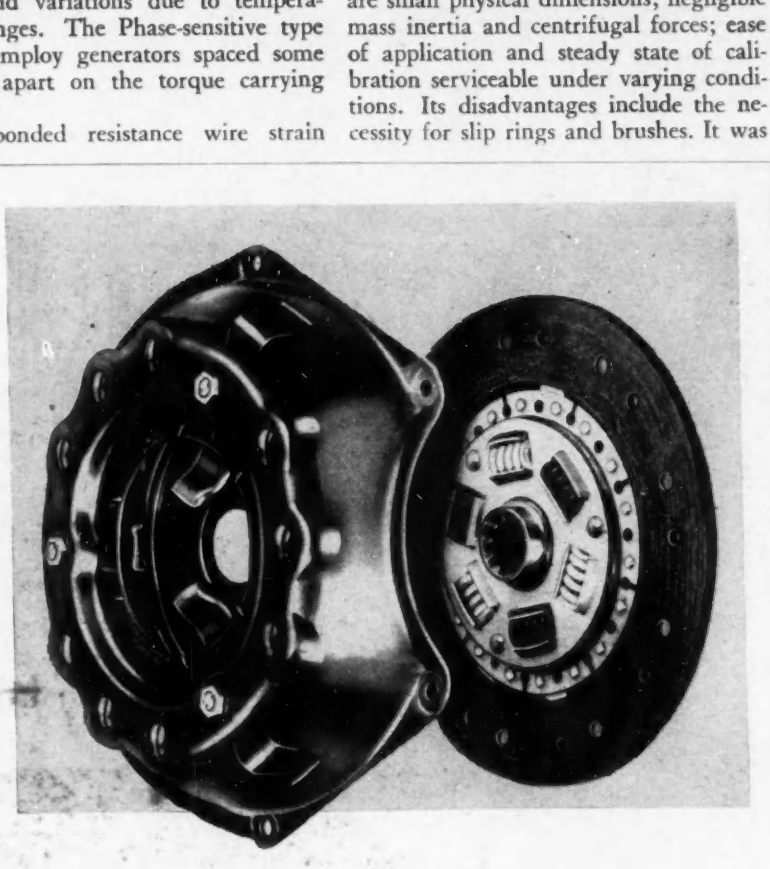
Commenting on this paper by C. H. Gibbons, Baldwin Locomotive Works; Dr. Ruge, Ruge de Forest; Dr. Meir, Bucyrus-Erie Co., and S. C. Heth, J. I. Case Co., thought the electronic strain gage (calibrated resistor) presents the ideal method of gaging and accurately recording actual torque input on harvester components. He referred to the torquemeter described in the paper.

This is not the engineer's utopia, however, because it requires special preparation for every application and a rather substantial amount of costly equipment as an adjunct to fully serve its purpose. Considering the wide range of loads on combine components, he thought that at least two torquemeters would be required to obtain suitable sensitivity. Special training as well as an intimate knowledge of all functions involved is required in using the torquemeter.

Most of the facts accumulated to date have been amassed through use of shear devices and spring release mechanisms such as jump clutches which have been dynamically calibrated while being connected to a conventional dynamometer. Some information has been obtained by driving individual components by separate gasoline engines on which vacuum gage readings have been calibrated in terms of hp in operation through a dynamometer. Although this method has given some interesting figures, the effect of the inertia value of the engine and sensitivity of reaction has always left results open to question.

Frank G. Tatnall, Baldwin Locomotive Works, believes that the experimental evaluation of occasional overloads and impacts in the field is more important through torque measurement for the designer than average torque under normal conditions. He quoted Almen and Boegehold of General Motors Research as stating that normal stresses are so low as to be negligible from a fatigue standpoint and that occasional low gear full power pulls exert maximum stresses in which not over 100,000 such cycles are expected to be encountered in normal life of the equipment.

Experience shows, Mr. Tatnall said, that occasional overloads use up so much of the fatigue life and produce so much damage in the high-stress-end of the



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tigue or life curve, even though no definite crack or failures appear, that these overstresses may be considered the maximum factor in stress or torque studies. This means that not average torque but peak torque is important. It means torque measurement in field tests and the carrying of a multi-element moving mirror type oscillograph in the farm equipment under test and it means an engineering job of interpretation that is more critical than the actual job of obtaining the test data.

The wire resistance gages described by the authors can serve many uses other than measuring torque and horsepower. They can be simply applied to measure draw bar pull, acceleration pressure forces and to obtain direction and magnitude of principal strains.

Chairman of the Power Driven Machinery Session was J. R. Mohlie, Oliver Corp.

Mechanization of farming operations has generally followed a need for producing with less labor because of its unavailability, according to K. W. Anderson, Deere & Co. Wherever mechanization has been accepted, costs have been reduced and production has increased, he said, after he had been introduced by Session Chairman E. W. Lehman, University of Illinois professor.

Acreage used for various crops has a decided influence on farm equipment requirements, he said in his paper on "Current Influence of Mounted or Integral Equipment." Row crops, such as corn, cotton, soybeans, potatoes, peanuts, etc., rank first with 44.7 per cent of the total farm acreage in the United States. Next comes the broadcast crops—wheat, oats, barley, rye, rice, etc., totaling 33.6 per cent. Hay, including seed, ranks third for 21.7 per cent.

The current all-purpose tractor is a result of the strong influence of row crops and the mechanization of cultivation. The same power unit serves adequately for haying, the two categories equally 66.4 per cent of the whole farm acreage.

Customer acceptance of integral machines of all types increases in proportion to the ease of attachment, provided the function of the implement is not impaired. A live subject now is the request for a hydraulic system with a source of power ahead of the master clutch that will provide for multiple function control. Thus the elimination of hand levers makes an important contribution to the ease of implement attachment.

Mr. Anderson reviewed in some detail types of integral machines in which there is widespread interest. One of the relatively new integral machines is the front end loader, not completely descriptive, because of its use around the farm for a hoist in a multitude of services.

As the market becomes more competitive tractor engineers will be faced with the problem of better adapting tractors for use with front-end loaders because of the extra weight which often exceeds the rated capacity of tires and imposes a severe burden on wheels, rims, spindles, bearings, steering and frame.

Although farm equipment manufacturers have concentrated their attention on mechanization having to do with the production and processing of crops, there is much other useful work on the farm to be done, a lot of which has been neglected because of the amount of hand labor involved. Such work includes earth moving operations in connection with soil and water conservation; the building and maintenance of roads and yards. To handle this type of special integral equipment the tractor must have some form of hydraulic power control and

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provide for suitable means of attachment.

Analyzing the forces imposed by common mountings on conventional tractors discloses easily-overlooked facts in enthusiasm for new designs, observed D. C. Heitshu, John Deere Harvester Works.

In his paper, "Load Reactions, Weight Transfer, and Operational Effects Resulting from the Mounting of Implements on Tractors" he shows that each type of implement merits special consideration in mounting or hitching to eliminate power waste.

That good steering, stability, and an efficient tractive effort necessitate proper weight distribution of tractor implements, was demonstrated by Mr. Heitshu in several examples.

Present farming methods and equipment would be revolutionized by a successful two-way tractor, advised A. W. Turner, U. S. Department of Agriculture.

Asserting in his paper, "Tractors with Facilities for Equal Forward and Reverse Operation; and Their Possibilities for Increased Adaptability for Farm Work," that modern tractors were being designed for horse-drawn implements and are based too much upon automobile design, generated vigorous controversial discussion.

Mr. Turner outlined specifications for such an all-purpose tractor that would offer flexibility, comfort, and convenience to the operator as well as economy in cost, operation, and maintenance. The Russians have been using an electrically-operated two-way tractor for two years, he reported.

Following Mr. Turner's paper, J. B. Barnum, of Salt Lake City, Utah, a farmer and manufacturer, showed a motion picture and described his two-way hay cutting machine. The two-way tractor carries two seven-foot sickle bars and operates at 8-10 mph, and has a reverse steering gear.

A. P. Balzer, a farmer from Mountain Lake, Minn., showed his motion picture of two-way equipment he has built. He has been building his own two-way tractors since 1937.

On the first question period panel Elliott Adams, Massey-Harris Co., took the place of G. E. Everett. The others were T. H. Oppenheim, New Idea, Inc.; Martin Ronning, Minneapolis-Moline Power Implement Co.; H. D. Hume, H. D. Hume Co., and George Kriegbaum, International Harvester Co.

The panel held that a proposed "two-way" tractor would be excessively complicated. Full gear set in reverse is seldom needed, Mr. Ronning thought.

Mr. Kreigbaum saw little advantage in the forward-and-reverse tractor in answer to a question. Most agricultural operations "follow a mark," and the maneuverability of the conventional machine appeared to him to have considerably more advantages, in an answer to a question.

Thousands of farmers have been using old car and truck chassis as tractors to increase productivity. In haying, buck rakes prove to be a valuable implement when attached to a vehicle chassis, but on the rear end of a tractor running backwards, the operation is far easier and faster, Mr. Oppenheim said in response to another question.

Attaining sufficient traction to transmit large horsepower at low speeds and with a variety of surface conditions was pointed out by C. T. O'Harrow, Allis-Chalmers Mfg. Co., as a serious problem of the tractor industry.

Of the many factors involved in bettering traction efficiency, two stand out: a greater knowledge of each soil condition and increased area of surface contact. These facts became evident after

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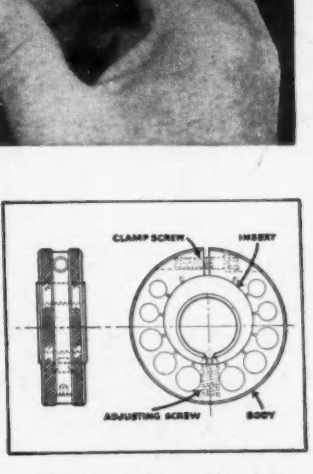

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conducting numerous tests described by Mr. O'Harrow in his paper, "Traction Efficiency."

He was the first speaker at the Thursday morning session, of which E. F. Norelius, Allis-Chalmers consulting engineer, was chairman.

Problems of military vehicle mobility begin where the agricultural problems end, said W. A. Gross, Jr., and A. D. Elliott, Army Ordnance, in the second paper, "Traction as Influenced by Soils and Their Conditions."

Since traction is influenced more by soil shear strength than by any other soil property, traction elements should be designed to fully exploit this characteristic. Proper flotation is also an important element in mobility. Ordnance tests, carried out with the assistance of the SAE Controlled Soil Testing Committee, proved increase in traction is not proportional with increased weight of the same vehicle.

H. E. Churchill, research engineer of Studebaker Corp., commented on both papers. He said that from Mr. O'Harrow's paper it is evident that the mechanical details are well known. However, he was amazed at the tremendous power losses due to resistance based on such figures as 40% efficiency. He realized that agriculture is not interested in operating vehicles in soils such as the Army encounters at the lower plastic limits. However, he believes that the studies of Ordnance on dynamic and static shear of soils should be of value to the tractor industry.

Paul Huber, chief engineer, General Motors Proving Grounds, pointed out that at the start of the SAE Controlled Soil Testing Committee's work little was known about testing a track. He commented on the great progress that has been made during the war years in the methods of testing tracks and the knowledge gained as shown in both Mr. O'Harrow's and Mr. Elliott's paper.

R. W. Smith pointed out that conversion of the wheel tractor to a crawler type was a practical solution under many circumstances. The B. F. Goodrich engineer cited figures to show tractive increases, and enough work has been done on adjustable tracks to make the application feasible.

Session Chairman B. G. Van Zee introduced L. A. Gilmer, Oliver Corp., who demonstrated that the long awaited power plant for the 20 to 45 maximum bhp wheel-type factor tractor now using gasoline is the diesel engine. This is especially true in areas where taxes or nonavailability makes use of gasoline prohibitive.

Diesel initial cost must be lowered to compete with the gasoline engine and take advantage of the diesel's operating economy. In his paper, "Diesel Engine Requirements for Farm Tractors," Mr. Gilmer said that this can be achieved by designing for a specific use only and by reducing injection equipment and accessory costs so the overall price difference to the farmer is kept below $400 to $500.

Cost-conscious farmers are finding that diesel engines operate at higher thermal efficiency on less and cheaper fuel, observed H. F. Bryan, International Harvester Co., the second speaker.

Available data shows that with present fuel prices the diesel will deliver more than twice the number of horsepower hours per dollar at full load than the gasoline engine. On the debit side of the ledger he emphasized higher initial cost and fixed charges in his paper, "Economics of the Application of Diesel Power to Farm Tractor Operation," as the major handicap to wide diesel acceptance.

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starting of diesel engines was laid to the petroleum industry by F. G. Shoemaker, Detroit Diesel Engine Division, GMC. He felt that what was done for the aircraft industry in development of special fuels, should be done for the diesel engine.

Development of a 12-hp air-cooled diesel, suitable for operating electric generating sets more efficiently and more economically than the gasoline engine, was reported by J. C. Hoiby, of D. W. Onan & Sons, in the third paper.

Mr. Hoiby points out in his paper, "Development of the Air-Cooled Diesel Engine," that such a diesel will run twice as long as the gasoline engine between service periods, would operate at about half the fuel costs, and more satisfactorily meet safety and insurance requirements. He expects that lower cost, lighter weight, and simplicity of manufacture will make the air-cooled diesel available in ratings up to 30 hp.

The afternoon question panel consisted of Mr. Gilmer, Frank Schwilk, Continental Motors Corp.; Harold Smith, Buda Co.; O. D. Treiber, Hercules Motors Corp.; A. W. Pope, Waukesha Motor Co., and Mr. Bryan.

Mr. Smith answered a question by reporting that most of the engine companies are working on development of small diesel powerplants, which he thought would become a large factor in agricultural machinery.

Another development project commanding the attention of diesel engineers is quick starting in cold weather. E. C. Ginn, Continental Motors Corp., felt that this development is of great importance, particularly because tractors often stand idle for long periods. Mr. Schwilk read his colleague's paper.

The farm's second tractor, far from being a luxury, is usually a necessity, because of the increased number of uses to which the farmer is applying power to increase farm produce, Mr. Gilmer said in answer to another question.

Mr. Pope does not look for any change in the basic cost of production of diesel fuels and gasoline. The difference in basic cost of diesel fuel and gasoline is only one cent. As distribution and availability of the two come closer together, the advantages of one over the other will decrease.

The matter of cost and availability of fuels is very important, Mr. Treiber said. He has been told by fuel men and officials of the Department of Interior that by 1966 we will probably have to import much of our fuels. Internationally, the nation that has the oil will win out, and that gains made by the socialistic nations does not augur well for the capitalistic nations. This nation should conserve on petroleum fuels, he said.

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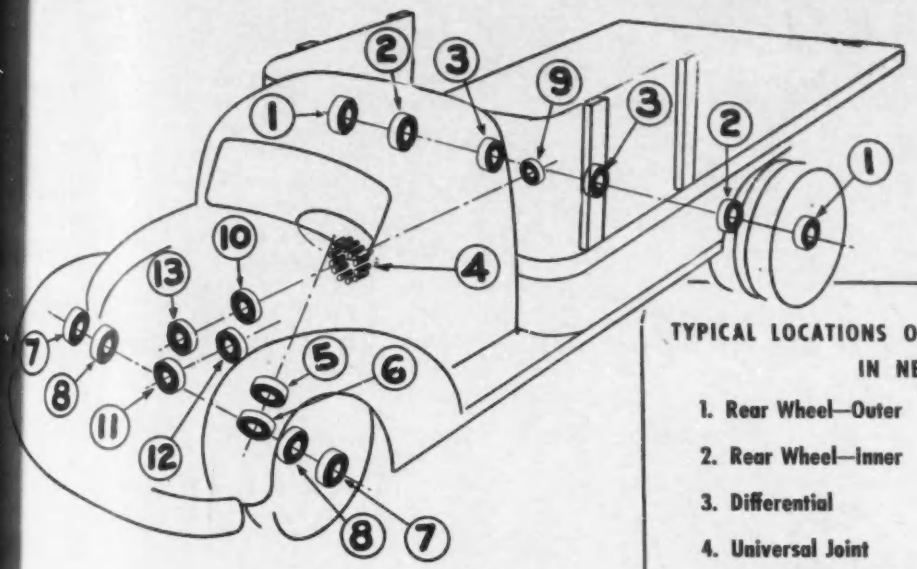
British Columbia Group: Victor J. Barclay (M).

Canadian Section: William Roy Aikins (M), Donald M. Chisholm (A), Corlis



TYPICAL LOCATIONS OF HYATT ROLLER BEARINGS IN NEW TRUCKS

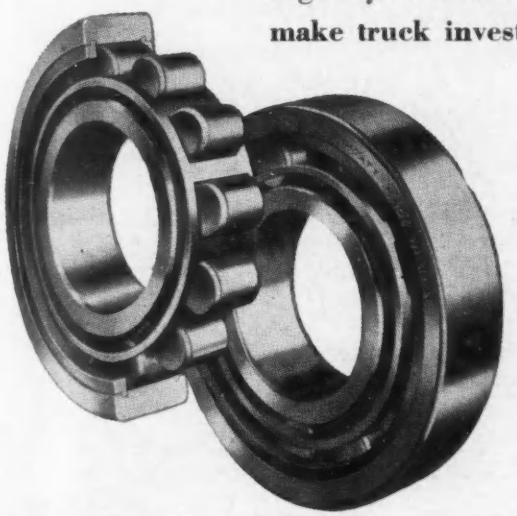
1. Rear Wheel—Outer
2. Rear Wheel—Inner
3. Differential
4. Universal Joint
5. Steering Gear—Upper
6. Steering Gear—Lower
7. Front Wheel—Outer
8. Front Wheel—Inner
9. Rear Pinion
10. Mainshaft Pilot
11. Front Counter Shaft
12. Rear Counter Shaft
13. Clutch Pilot

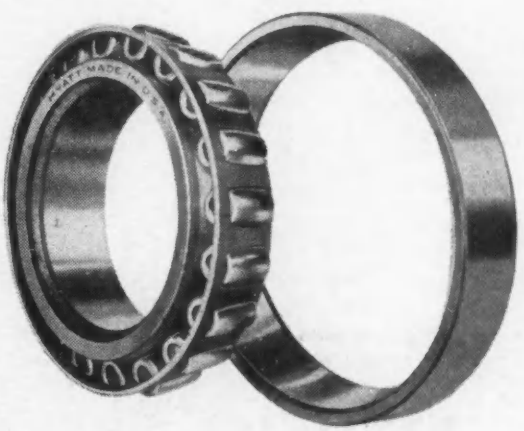
HYATTS EXTEND TRUCK LIFE

Whenever a thoughtful designer draws upon his past experience, he writes in his specifications—Hyatt Roller Bearings.

In the typical 1947 truck illustrated above, eighteen vital positions are protected by the rolling elements of Hyatt Roller Bearings. Hyatts extend truck life and make truck investments pay off in more efficient service.

For more than half a century automotive engineers have recognized the importance of writing "Hyatt Roller Bearings" into their specifications. Hyatt Bearings Division, General Motors Corporation, Harrison, New Jersey; Detroit, Michigan.





HYATT—QUIET ROLLER BEARINGS

G. Keyes (A), Sydney R. Skelton (A), Laurence Cotter Thomlinson (A), J. V. Watts (A).

Chicago Section: Francis E. Edwards (M), Otto R. Hills (M), William Lawrence Kolb (J), Walter J. Metzger (A), Frank L. Monaco (M), Henry W. Schmidt (M), Donald Leroy Whitehouse (A).

Cincinnati Section: J. W. Grafton (A); Hall-Rattermann Oil Co. (Aff.) Reps: William E. Ferris; William Harpenau; Urban F. Wenstrup; Cason Rucker (A), Gustav F. Windgassen (M).

Cleveland Section: Walter A. Alaska (J), William R. Galloway (J), W. W. Halstead (M), Starr W. Pearn (J), Ensign Donald G. Rambacher (J), Earl L. Sherman (J), Robert W. Smith (M), Ralph W. Sohl (M).

Detroit Section: Samuel B. Allen (J), Theodore Bargman (A), Don L. Brown (M), Albert J. Chendes (A), Robert E. Decker (J), Frank J. Denny (J), Charles P. DeVoss (M), Verner J. Fisher (A), Albert Hollerud (J), George J. Huebner, Jr. (M), Fred A. Jenness (A), Ray F. Johnson (A), Clifford Fraser McKeown (A), Robert M. McVeigh (M), James Alvin Miller (J), John J. Morrow (A), Robert M. Palmer (A), Ellis John Prentice (M), George Lewis Radamaker (M), Lawler B. Reeves (A), William Gipson Rohr (J), Claude Edward Schaefer (J), John F. Schmidt (A), Lyle A. Wade (M), William H. Wanderer (M).

Hawaii Section: Stephen Joseph Michelstein (M).

Indiana Section: Rex E. Gage (M).

Metropolitan Section: Ward H. Brigham (M), Elwood M. Easton, Jr. (J), Harold L. Ehlers (J), Preston Sumner Eldridge (J), Earl W. Estelle (A), Luigi M. Ferrari (M), William A. Gardner (J), Arthur P. Gluck (M), Peter P. Guarneri (M), Richard Ellsworth Hitchcock (J), George F. Hunt (M), Antonio Idone (A), Thomas Manning Kiely (J), Arthur F. Moricca (J), Frank Pagano (A), Chester Charles Pearson (M), Thomas D. Rae (M), Jacob F. Reif (A), Ernest M. Schneider (J), Thomas C. Tarbox (J), Edmund Thelen (M), Harry W. Van Horn (M), Stanley Evert Varner (J), Elwood C. Walker (J), Charles A. Wolf (M), Don R. Woolf (M).

Milwaukee Section: Horace John McGaffigan (J), Homer W. Miller (J), Gordon Murphy (M), Bernard R. Weber (M).

New England Section: John F. Hart (A), Lt.-Col. Allan L. Harts (SM), Richard R. Metheany (J), Comdr. Wendell Wood Suydam (SM).

Northern California Section: Ernest L. Walters (M).

Northwest Section: F. B. Harwood (A), George W. Marshall (J), Paul J. Ruple (M).

Oregon Section: William S. Hood (M), Glenn W. Snook (A).

Peoria Section: William L. H. Doyle (M).

Philadelphia Section: Ralph Gallo (A), Edmund F. Higgins (J), Robert Joseph Reid (J), Capt. James A. Scobie, Jr. (A).

Pittsburgh Section: J. Louis Bossart (A), Charles L. Kent (M).

Salt Lake Group: William H. Wilson (A).

Southern California Section: Don W. Driskel (J), Richard L. Hayman (M), Julian

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Southern New England Section: Mario Louis Garangelo (J), Chris F. Kimball (A), Gen Min Lee (J), John C. Selden (M).

Syracuse Section: John F. Puro (J), James J. Wilder (J).

Twin City Section: W. Evert Welch (A).

Virginia Group: James William Rankin (A).

Washington Section: Hobart S. White (SM).

Wichita Section: Donald C. Simon (J), Marshall Leroy Werth (M).

Outside of Section Territory: E. H. Holloway (M), Clifton C. Rousseau (A).

Foreign: Pierre Cibie (FM), France; Charles Lindsay Goodacre (FM), England; James Stuart Hamilton Moore (FM), England; Percy Morrey (FM), England; Robert Puiseux (FM), France; Jaime Alberto Vendrell (FM), South America.

Applications Received

The applications for membership received between Aug. 10, 1946, and Sept. 10, 1946, are listed below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

Baltimore Section: Willard C. Eichelberger.

Buffalo Section: Alfred C. Ryan.

Canadian Section: George Albert Dowling, Harold Murray McLean.

Chicago Section: Archie Nelson Brion, Burt N. Felz, James Alfred Fitzgerald, Perry L. Houser, Herbert Blood Hubbard, Einar John Johnson, Ralph D. Mancinelli, Leslie O. Parker, Jr., Walter H. Schackenman, Swen Herbert Stone, Robert W. Sutton, Alfred F. Zornow.

Cleveland Section: Ralph E. Grey, Jr., Jerry V. Koski, James J. Skelly, Robert Wayne Wilson.

Dayton Section: Robert E. Arndt.

Detroit Section: Loren E. Bartling, Nelson R. Droulard, Robert B. Edgar, Paul A. Engstrom, Ralph P. Horan, William H. Kreipke, Jr., John W. Krygier, William Parshall Kalb, Webster Campbell McDonald, Jr., John J. O'Blenis, Walter W. Olin, Raymond C. W. Peterson, Gordon T. Sawyer, Robert W. Seavy, Harvey R. Stone, George C. Trevarthen, Robert Waite, Mahlon E. Wood, Robert M. Worth.

Hawaii Section: Douglas Richards, H. J. Roblee, Tadashi Tomonaga.

Indiana Section: William E. Judd, James P. Leamon, Abraham Smaardyk, Hubert L. Suddeth.

Kansas City Section: Claude L. Johnson.

Metropolitan Section: John Baier, E. L. Barringer, Leo F. Cestari, Jr., George W. Jackson, Albert Edward Lee, Bernard H. Macy, Michael J. McKenna, David Miller, John P. Soule, William R. Stein-

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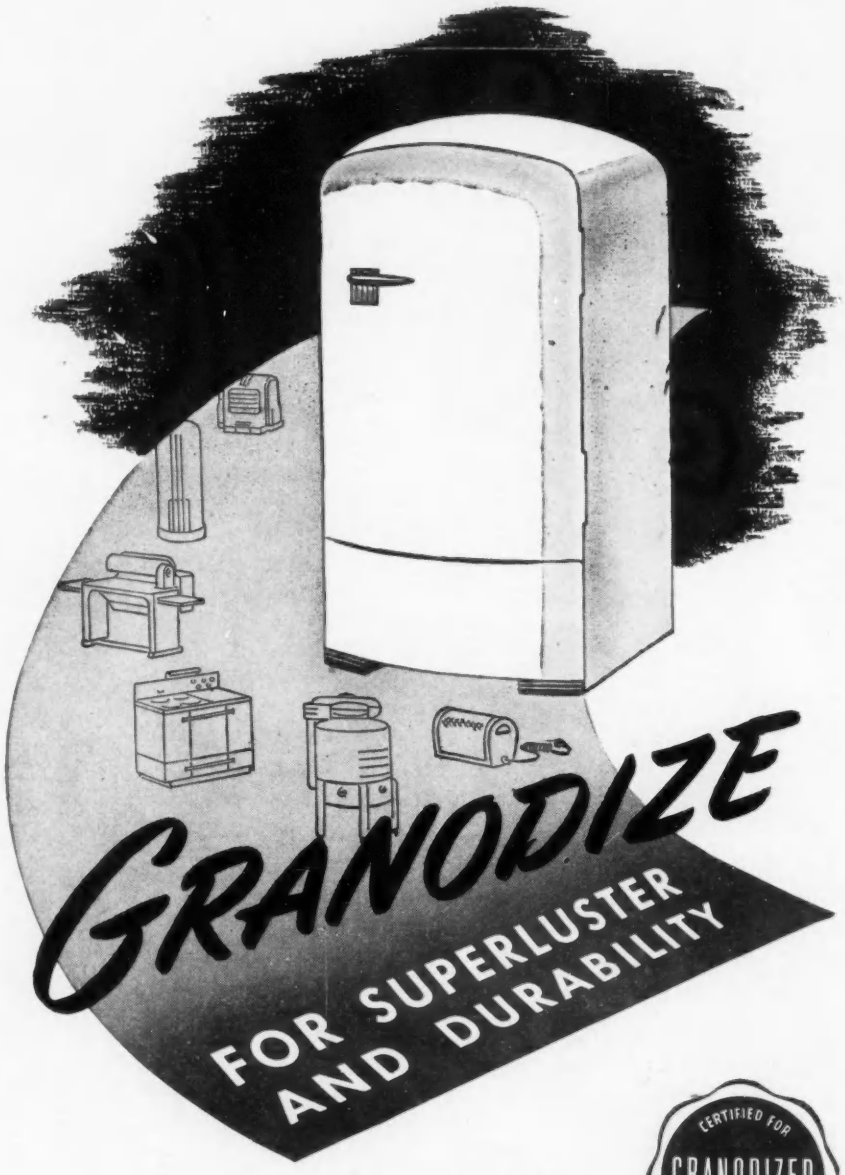

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Mid-Continent Section: Edgar Bauter... William H. Easton, Otis L. Spilman.

Milwaukee Section: Herbert Neal Berge... Wilford B. Burkett, Wilbur J. Peter... William Richard Proteau, Joseph R... Sutton, William A. Wing.

New England Section: William A. Leary...

Northern California Section: Albert Kemper Branson, Fred V. Hall, Charles Edwin Reid-Selth.

Northwest Section: Lewis Holmes Bunnett.

Oregon Section: Richard Edgar Smith...

Philadelphia Section: Samuel E. Baily, William Howard Balentine, Roderick H. Clarke, Paul Robert Elder, Robert Meagher.

Pittsburgh Section: George Anderson Hinckley, Carl H. Koch, Kenneth G... Scantling.

Southern California Section: George Douglas Albert, John Peter Calligeros, John C. Chiabotti, David Stuart Craven, George E. Diethridge, Hollis S. Dolan, E. F. Knoll, William John Monsma, Clinton B. Ridgell, Geneste Radnor Taylor, William Thorpe, Ralph Simpson White, Jr.

Southern New England Section: Gilmour... N. Cole, Richard W. Henry, A. Burton Jones, Jr., George William Kosha, Jr., Fred E. Stockwell, Richard S. Woodbury.

Texas Section: James Burr Powell, Frank M. Stripling.

Twin City Section: William A. Anderson, Durward C. Mattison.

Washington Section: John Fullemann, Eugene Louis Klein.

Western Michigan Section: Alfred C. Boorman, Richard Junior Alkema.

Wichita Section: Paul E. Sutoris.

Williamsport Group: John W. Akeley.

Outside of Section Territory: E. C. Barnhart, Fred Errol Davis, Joseph H. DeFrees, I. Edward Johnson, David Boone Mallett, Robert Andrew MacGregor, W. G. Roloson, William Lee Schroyer.

Foreign: Thomas Redvers Beady, England; Michael Stephen Crosthwaite, England; James A. Hand, China; Joseph William Milton, England; Gerald Edgar Stevens, Australia; William J. Wigmore, South Africa.

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